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CHEMICAL & METALLURGICAL ENGINEERING

VOLUME 38 NUMBER 1

A McGRAW-HILL PUBLICATION—ESTABLISHED 1902

S. D. KIRKPATRICK, *Editor*

January, 1931

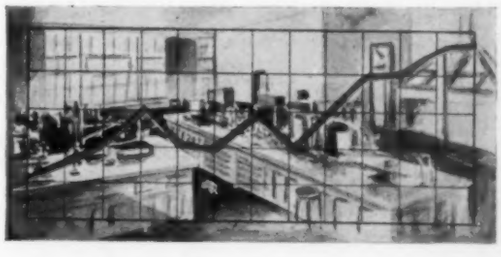
Constructive Competition

CHEMICAL industry faces a period of intensified competition. Creative science, backed by vigorous engineering development, has produced new products and processes that are actively competing for an all too limited market. Overstimulated demand and frenzied bidding for materials have given way to highly competitive selling in which prices are sometimes being forced to non-profitable levels. More than ever before in chemical industry is there the vital need not only for lower costs but for accurate knowledge of product and ability to anticipate the market trends of business.

For competition in chemical industry is not limited to the usual price, quality, and delivery factors for the individual product. Often more important is the newer and more aggressive competition between commodities. A new synthetic displaces a natural material because it is available in quantity and at a lower price. Or it may possess more desirable properties that permit it to enter an entirely new market for which the older product was ill adapted. If it completely fills the new need and is reasonably priced, it wins a place for itself without direct competition. If, on the other hand, its only advantage is cost, it is likely to precipitate a price war that will end only with the chaotic displacement of the more costly material. Both forms of competition can undoubtedly be justified from an economic standpoint. But for the lasting good of chemical industry, the more constructive activity is that directed toward new and relatively non-competitive uses.

Such subjects are of more than academic interest to the chemical engineer. There never was a time when more of his products were entering the world's market on a keenly competitive basis. Synthetic methanol competes not alone with the product of the wood distiller but with denatured alcohol from molasses, which in turn competes with ethanol and glycol synthesized from ethylene. Synthetic ammonia competes not only with byproduct ammonia but with Chilean nitrate, cyanamide, and even caustic soda. The situation is further complicated by the closely related competition of processes, although fortunately this situation lends itself more readily to technical and economic evaluation.

But just as research has created the problems of the newer competition, it is in that direction we must look for their solution. The studied methods of the laboratory will prove more effective than the mad bartering of the produce market or the stock exchange. Chemical industry today holds promise of great pecuniary reward to those who, through technical and commercial research, can guide competition into more profitable and therefore more constructive channels.



Chemical Engineering

Yesterday, today, tomorrow

An Editorial

AS A STIRRING CHALLENGE to chemical engineering initiative and industry, the depression of 1930 was not without its benefits. Faced with the absolute necessity for lower costs and improved processes, there has been a substantial increase in production efficiency. Spurred by an intense and vital interest in the development of new products, properties, and projects, the chemical engineer has been called upon to translate the results of research from laboratory to plant with a maximum of speed and thoroughness. This creative activity, combined with the diversity of output and the inherent flexibility of chemical processes, helped to maintain a higher level of production than characterized industry as a whole. Likewise as we go farther into 1931, it is apparent that these are the forces on which we must depend for stimulus and support in the gradual process of business recovery.

Whether we wish it or not, 1930 is the basis on which the progress of the present year is most likely to be judged. It is desirable, therefore, to look back over certain of our disappointments as well as our achievements to discover in them, if possible, the technical, economic, and professional trends that should prove most helpful to the chemical engineer.

Technical Achievements

ANY LISTING of the accomplishments of technology in 1930 must necessarily involve a certain overlapping, because of the spread between research and commercial exploitation. Thus the duPont production of higher alcohols is but a part of the older project of nitrogen fixation and methanol synthesis. The successful operation in New Jersey of the first commercial plant for the hydrogenation of mineral oil follows several years of research and development in Louisiana and elsewhere. The greatly increased use of stainless steel in building construction during 1930 was a logical step from the industrial application of these newer metals and alloys. Hence the difficulty in gaging technical projects within the limits of a calendar year.

By any measure, however, the advance in the new technology of high pressure and temperature has been the outstanding chemical engineering achievement. It has been made possible largely by the solution of many practical problems in the design and construction of equipment and the development and selection of engineering materials. With it have come many refinements in process control—the perfection of new instruments and the application, through the photo-electric cell, of new principles of electronics which seem to open up untold possibilities. Alloy steel forgings are in service at pressures of 15,000 lb. per square inch, while welded pressure vessels weighing as much as 200 tons have been built for pressures upward of 1,000 lb. per square inch and temperatures above 1,000 deg. F. Yet it seems we are only at the threshold of what may ultimately be expected from the application of this new technology.

As nitrogen fixation has grown to be one of the largest chemical enterprises in the United States, there has come a gradual recognition of our independence of any foreign source of supply for this most important material. The industry has expanded from a daily output of less than 300 tons of synthetic ammonia in 1929 to 450 tons in 1930, and plants are now under construction or immediately projected which will bring the capacity to 850 tons in 1931. In the meantime, the Chilean nitrate industry fights with its back against the wall, hoping by drastic reorganization to recoup at least a part of its once supreme monopoly.

Synthetic organic chemistry contributed more to industry in 1930 than in any recent year. In addition to the butyl, amyl, and higher alcohols and the practical doubling of the production of synthetic methanol, the solvents field saw ethyl alcohol, ethyl ether, ethyl acetate, acetone, and as many derivatives being produced on an increasingly large scale by synthetic processes. Likewise, diphenyl made a serious bid for industrial application as a heat transfer and boiler medium, while its chlorinated derivatives were finding use as non-flammable solvents, waxes, and insulating compounds. Midgely and Henne proved that the combination of a mechanical engineer and a research chemist can make a new non-toxic and non-flammable refrigerant out of fluorine, chlorine, and methane. New organic disinfectants, insecticides, fungicides, and germicides were produced in 1930 on a scale that promises to save millions to agriculture and incidentally prove a boon to the doughboys in the next war. New, delicately colored plastics, synthetic resins for lacquers and quick-drying varnishes, cellulose acetate in plastics, and transparent wrappings, all are evidence of this greater activity that has characterized recent technical progress.

Professional Progress

MAJOR activities having to do with the professional status and progress of chemical engineering have been of a high order. The colleges and universities have accepted the important responsibility of training and equipping chemical engineers for the severe and arduous demands of their high calling. No longer have these men in charge of chemical engineering education wasted time with academic quibbling over the definition of the subject and its relation to the basic sciences of chemistry, physics, and mathematics. They have worked hand in

hand with the industries that use their products and have shaped their chemical engineering courses to meet the needs of the day.

Gradually the function and place of the chemical engineer is being recognized and accepted by the older branches of engineering. The industrial world in general is learning to differentiate between the work of the chemist and the chemical engineer, and to contrast their activities with those of the mechanical, civil, and electrical engineers. Within the profession there has been substantial agreement as to the field and application of the unit operations and the line of demarcation between the chemist and the chemical engineer, although some matters of definition are still the subject of earnest debate. Even the American Institute of Chemical Engineers has recently had within its ranks an animated discussion of its definition of membership requirements. Despite the confusion of issues and the semblance of controversy there is general agreement as to the major objective: viz., to raise high the standards of the profession and to maintain it as a separate, independent branch of engineering, dependent upon but subordinate to neither the sciences of chemistry, physics, and mathematics nor the arts of mechanical, electrical, and civil engineering.

Through the preliminary organization of a process division, the American Society of Mechanical Engineers has recognized the increasing importance of the group of process industries and the role played therein by the mechanical engineer as contrasted with that of the chemical engineer. Much remains to be done to define and clarify the position of these two branches of engineering, but through their own professional organizations they may logically be expected to work out a proper co-ordination of their divergent, as well as parallel, interests.

In a year's continued growth, the American Chemical Society has had its organic and financial structure under scrutiny and appraisal, emerging with an enlarged and strengthened directorate and a new plan of business organization. The Electrochemical Society became a corporate body in 1930 and in so doing dropped the word "American" from its name, thus giving expression to the international character of its pioneering work. The American Institute of Chemists, concerning itself largely with the economic status of the chemist, has also strengthened its position and may well look forward to greater influence and recognition.

Economic Advance

AS CHEMICAL industry of 1931 looks back at a year that was rather disappointing from a business standpoint, there is a certain amount of comfort in noting that the records compare not unfavorably with that of even as good a year as 1928. Furthermore, as compared with other industries during 1930, the position of the chemical industry must be regarded as extremely favorable. For example, Standard Statistics reports that the total profits of the thirteen leading chemical companies (excluding duPont, because of motor holdings) during the first nine months of 1930 declined but 18.7 per cent from the peak of 1929 as compared with the recession of 35 per cent shown by the aggregate corporate earnings of all industry. Compared with the corresponding period of 1928, however, these chemical companies showed an actual increase of 4.8 per cent in 1930, while all corporate earnings for the same period showed a decrease of 19.3 per cent from 1928.

What of the Future?

BECAUSE of chemical industry's basic relations to other industries, its immediate future is dependent to some extent upon the activity of business as a whole. Yet there is this important difference: the very diversity of chemical production gives it an encouraging stability. Perhaps fertilizer or oil refining, both of which had comparatively good going in 1930, may trim their sails in 1931, but the expected recovery of construction, automobiles, steel, textile, and rubber industries will help to level out the curve. In the meantime, new products are germinating and in them lies the basis for the prediction, made before in these columns, that the new industries which will characterize our future progress are most likely to come from the chemical laboratories.

Dr. Arthur D. Little, nobleman of science and industry, well expressed this view of the future in a classical address on Jan. 9, when he received the Perkin medal: "Since advances in chemistry react on every industry, while, conversely, every progressive trend in other industries makes new demands on chemistry, we may look with confidence to the chemical industries for contributions which should go far toward supplying the stimulus essential to the revival of our prosperity, and which the stationary or obsolescent industries can no longer furnish.

"Industries age like human beings. They have the hazards and diseases of childhood, the capacity for development in vigorous youth, the stability and strength of maturity, and the conservatism and atrophy of age. The railroads are old, the automobile is approaching middle age, but our chemical industries are still in their energetic and elastic youth, with their great development still before them. . . . Chemistry is a creative science, and the first chapter of its Book of Genesis is not yet written."

Nor do we have any intention of attempting such a task for chemical engineering. Suffice it to say that the tomorrow of our profession is assured if, as engineers, we build soundly and permanently on the foundation of such a science.

Sidney D. Kirkpatrick

Volume 38—*Chemical & Metallurgical Engineering*—Number 1

This magazine, *Chemical & Metallurgical Engineering*, is the successor to *Metallurgical & Chemical Engineering*, which in turn, was a consolidation of *Electrochemical & Metallurgical Industry* and *Iron & Steel Magazine*, effected in July, 1906.

The magazine was originally founded as *Electrochemical Industry*, in September, 1902, and was published monthly under the editorial direction of Dr. E. F. Roeber. It continued under that title until January, 1905, when it was changed to *Electrochemical & Metallurgical Industry*. In July, 1906, the consolidation was made with *Iron & Steel Magazine*, which had been founded eight years previously by Dr. Albert Sauveur. In January, 1910, the title was changed to *Metallurgical & Chemical Engineering*, and semi-monthly publication was begun Sept. 1, 1915. On July 1, 1918, the present title was assumed and weekly publication was begun Oct. 1, 1919. Monthly publication was resumed in March, 1925.

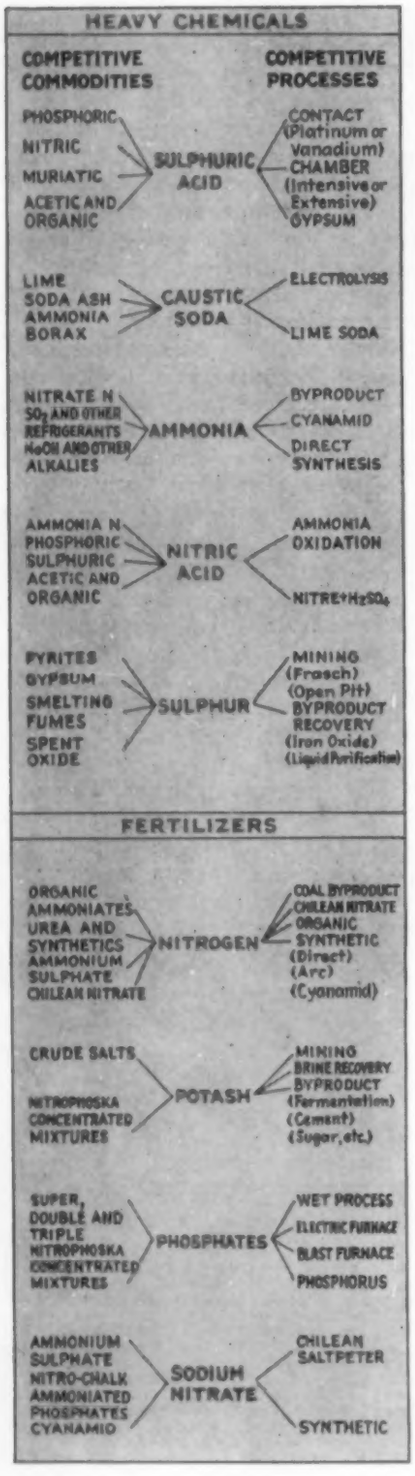
Dr. E. F. Roeber was editor of the paper from the time it was founded until his death on Oct. 17, 1927. After a brief interim he was succeeded by H. C. Parmelee. Ten years later, Nov. 1, 1928, Mr. Parmelee was made editorial director of the McGraw-Hill Publishing Company and was succeeded in the editorship of *Chemical & Metallurgical Engineering* by Sidney D. Kirkpatrick.

The editorial staff of the magazine comprises: S. D. Kirkpatrick, editor; H. M. Batters, market editor; James A. Lee, T. R. Olive, R. S. McBride, Paul D. V. Manning, and Richard Koch, assistant editors.

[Published each year as a matter of record.]

Chemical Industry's

The newer competition of



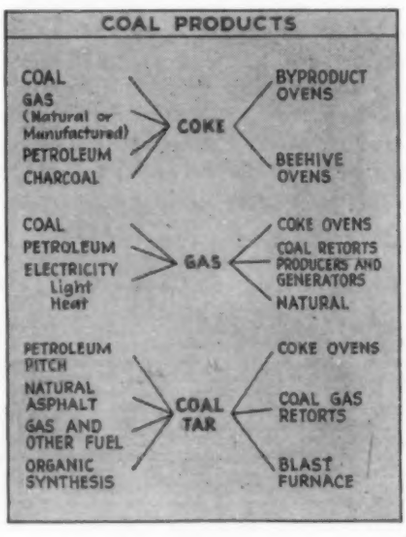
IN RECENT MONTHS chemical industry has been shaken, almost to its very foundation, by a civil warfare of commodities and processes. What a few years ago were interesting but abstract and academic examples of chemical interdependence have become intensely practical problems of present-day competition. They are of vital concern to all in industry, for unless these forces are guided and co-ordinated constructively, they threaten the very existence of more than one long-established business.

Literally hundreds of inter-commodity and inter-process battles are being fought every day in the chemical industry. Some are so commonplace as to escape attention except when a development such, for example, as the drastic reorganization of the Chilean nitrate industry, throws into bolder relief the relations between the natural and synthetic products. But is was synthetic methanol's dramatic entry into the anti-freeze market in direct competition with denatured alcohol that precipitated one of the most severe of the commodity battles. Produced as a by-product in the synthesis of ammonia and from the waste gases of other chemical operations, the new material became available on a large scale and at a lower price than that of its older competitor. Every effort was made to capitalize on this and other advantages of methanol, and likewise its competitors were not at all restrained from calling attention to its disadvantages and limitations. In the ensuing battle the opposing forces have drawn upon reserves from legal, governmental, and public health quarters. The warfare continues with every prospect of a long-drawn out and devastating struggle.

A more complicated but less spectacular contest is taking place among the other solvents for lacquers, rayon, paints, and plastics. Here the lead of fermentation butanol has been challenged by other higher alcohols, synthesized from widely different sources. With their derivatives and joint products, they have successfully invaded many of the older markets and are now turning their attack to other fields.

This newer and more aggressive competition is not confined to the synthetics. Recently one of the largest users of caustic soda and chlorine decided to switch to lime as a cheaper alkali. As a result he upset the nicely balanced market of the electrolytic producer. Likewise he helped to upset the price structure of the entire alkali industry. Furthermore, lime is not the only competitor, because synthetic ammonia bids fair to become an important industrial alkali, while borax, tri-sodium phosphate, and the newer sodium metasilicates are all likely to make greater progress in the future.

WHAT FORM of nitrogen will be used in the fertilizer industry of the future? Will it be natural or synthetic, ammonia or nitrate? Until recently superphosphate was the principal form of phosphorus used by the fertilizer manufacturer. Today, phosphoric acid produced in a



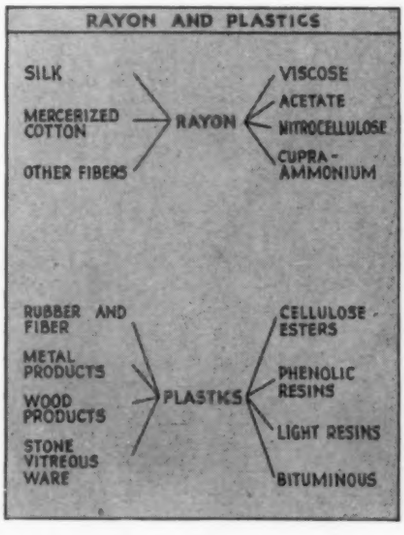
Most Vital Problem

commodities and processes

blast or electric furnace competes with the acid made by the wet process. Tomorrow, elemental phosphorus may likely be shipped in tank cars from Florida or Montana for oxidation at the user's plant. Potash is available from widely different sources and some new and interesting supplies are in prospect. Thus inter-commodity and inter-industry relations are certain to affect if not control fertilizer manufacture in the future.

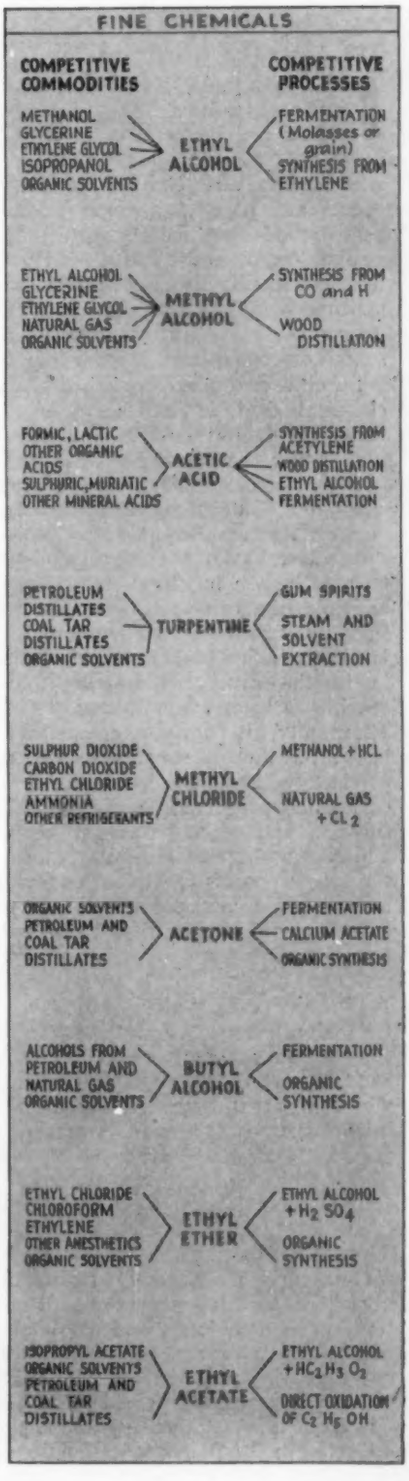
The recent history of the paint and varnish industry has been a battle of competitive commodities ever since nitrocellulose almost, but not quite, displaced the oleoresinous varnish. Now nitrocellulose faces a new competition from synthetic resins, while quick-drying finishes of the phenol-formaldehyde type are making a strong bid for popularity. Among the pigments, lithopone and zinc and titanium oxides have developed rapidly at the expense of older raw materials. In a broad sense, the paint and varnish industry has entered a competition of surfaces and surfacers. Nickel, chromium and cadmium are indirect but nevertheless important competitors.

Even as new an industry as electrical refrigeration has brought with it an intensive type of chemical competition. Ammonia no longer stands unchallenged as a refrigerant. Sulphur dioxide, methyl chloride, carbon dioxide, isobutane and the hydrocarbons, silica gel—all have their eyes on this growing market. More recently, dichloro-difluoro-methane appeared on the horizon with special claims for competitive advantage.



EXAMPLES of inter-commodity competition can be multiplied almost without limit. In many cases they involve the closely related problems of inter-process competition. Consider, for a moment, the sort of questions that are being asked in every one of the process industries: e.g. Will the acetate rayon process eventually displace viscose, cupra-ammonium, and nitro-cellulose? Would you build a chamber or a contact plant for sulphuric acid? If contact, would you use platinum or vanadium for the catalyst? Can ammonia oxidation completely displace Chilean nitrate in nitric-acid manufacture? If it does, where will we get our requirements for niter cake? Is acetic acid synthesis from acetylene more practical than fermentation or the direct synthesis from natural gas or hydrogen and carbon monoxide?

The answer to all these questions emphasizes but one fundamental requirement: viz., accurate, definite, indisputable knowledge of the technology and economics of each of these competitive processes. Likewise the solution for the less tangible, but perhaps more important, problem of inter-commodity competition must lie in this same direction. Therefore, in the pages that follow an attempt has been made not only to portray the competitive situation existing in the various process industries but also to point the way through scientific and commercial research to the most profitable and constructive solution for this vital problem.



An Economic Appraisal of Inter-Commodity Competition

By Theodore M. Switz
Chemical Economist
The Lehman Corporation
New York City

INTER-COMMODITY competition is a new phrase, but it describes a situation that is essentially as old as industry. It is the increasing frequency with which this type of competition occurs and its growing seriousness in certain fields that make it worthy of investigation at the present time. For inter-commodity and inter-process competition vitally affect not only sales managers and engineers but also research directors, bankers, and investors.

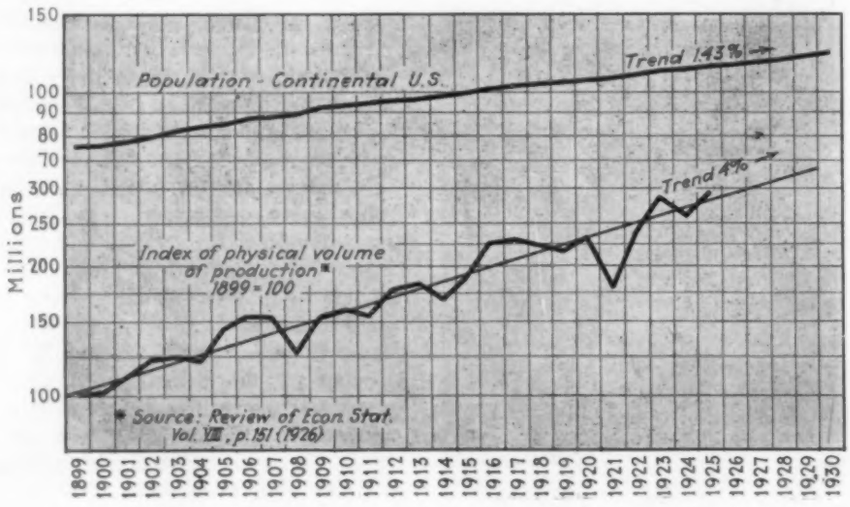
Specific examples are known to any chemical engineer and many are described in detail elsewhere in this issue; it is rather the purpose here to inquire into the factors common to the various cases, to consider their general economic significance, and to note the probable future trend. Of course, this phenomenon is known in other industries—for example, the competition between pipe lines and railroads, or between different varieties of breakfast foods—but it is in the process industries that it reaches a classic and typical form. Essentially, this type of competition is based on the development of a new product with physical, chemical, and economic properties sufficiently like those of another to be able to compete and take a share of the latter's market. Or a new process is worked out which, under certain conditions, is able to produce an old commodity more satisfactorily than by the methods in general use.

In order to explain the origin and full significance of inter-commodity competition it seems necessary to go back to certain economic fundamentals whose apparent triteness conceals their importance. Commodity production and distribution in the modern world have become so complex, and each in turn is subdivided into so many seemingly independent branches, that one tends to get the impression that production is carried on merely for its own sake. In feudal economy, social relations were more direct and technology simpler, so that it was obvious to everyone that work was carried on for four primary reasons: to provide man with (1) foodstuffs, (2) housing and shelter, (3) clothing, (4) means of amusement or enjoyment. Tools were used, but they were sufficiently simple so that their direct relation to the production of consumers' goods was evident.

The foundation of economic activity—the satisfaction of man's wants—has not changed from that time to this; the mainspring of our entire elaborate productive mechanism is still the satisfaction of these four broad but simple needs. But during the past two centuries great changes in the methods of production have taken place, and instead of a more or less constant amount of goods turned out each year, output has continually expanded. The manufacture of machines and other products used in the production of articles of consumption has developed until today it is represented by a whole series of apparently independent industries whose products are known as producers' goods. The relation of the growth of these industries to the expansion in the output of consumable goods, however, is obscured by the continually increasing technique of production and by the spread of modern manufacturing methods to all the backward quarters of the globe.

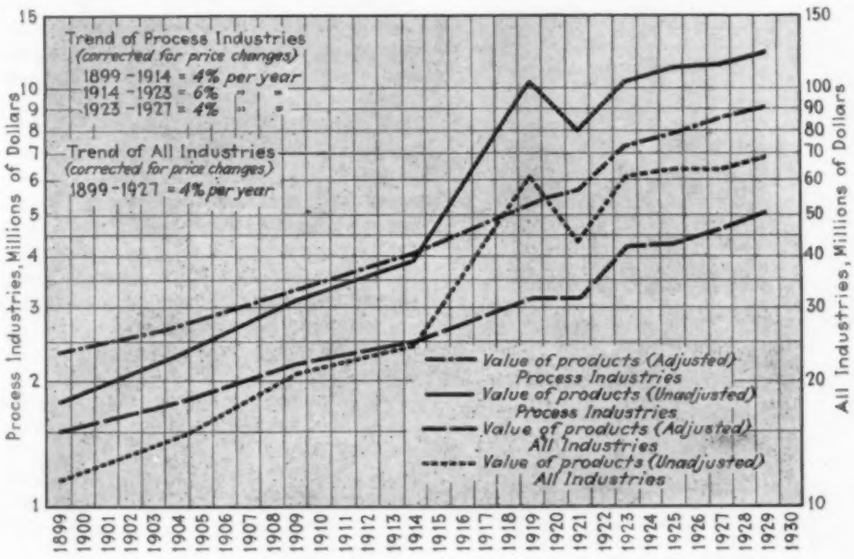
From this discussion it is obvious that there is an important distinction between consumers' goods and producers' goods, and that the output of any particular branch of the latter may not be increased indefinitely and independently but only in relation to the former. In other words, at any given time, the market for producers' goods (we omit a discussion of consumers' goods) has definite limits, although the truth of this statement may not be apparent during "new eras." This has a very direct bearing on the process industries, for, taken as a whole, they are outstanding examples of the producers' goods type. Some products, such as rayon, soap, or paints and varnishes, do go more or less directly to the final consumer, but the vast bulk of chemical production—acids, alkalis, other heavy chemicals, dyestuffs, and organic chemicals—are dependent on other industries in which they serve as raw materials.

ASIDE from the absolute size of the market for a given product, it is important to know how rapidly the existing market will increase from year to year. For the output of a product that is sold in a saturated market can increase no faster than the market itself expands. How rapidly is that most fundamental of all criteria of growth, the population of the United States, increasing? The accompanying chart shows the census figures and the Bureau's estimates for the last 30 years. The slightly concave-downward shape of the curve indicates a slowly declining



rate of growth. Indeed, calculation shows that the average rate of increase in population during the period 1900-1925 was 1.68 per cent annually, whereas a similar calculation for the decade 1920-1930 yields an average growth of only 1.43 per cent per year.

On the other hand, production, as would be expected, increased more rapidly. The general index of manufactures shown on the chart indicates that production (which in the long run must be the equivalent of consumption) gained an average of 4 per cent each year during the first 25 years of this century. Unfortunately, this index is no longer available, but a similar production index published by Standard Statistics shows an average growth of 3 per cent annually between 1910 and 1930, the difference being due principally to the weighting of the various series included. But either of these basic growth figures seems modest.


Trend of Process Industries
(corrected for price changes)
1899 - 1914 = 4% per year
1914 - 1923 = 6% " "
1923 - 1927 = 4% " "
Trend of All Industries
(corrected for price changes)
1899 - 1927 = 4% per year
Value of products (Adjusted) Process Industries
Value of products (Unadjusted) Process Industries
Value of products (Adjusted) All Industries
Value of products (Unadjusted) All Industries
Process Industries, Millions of Dollars
All Industries, Millions of Dollars

This is another factor that lies at the foundation of inter-commodity competition. For while newly developed products, like ethylene glycol or butanol, may show rates of growth as high as 20, 50, or even 100 per cent per year during their first few years while expanding into relatively new markets, this is not at all typical of the old and well-known bulk products of the industry, such as sulphuric acid, the production of which is increasing about 4.5 per cent per year; or explosives, 2 per cent; or dyestuffs, about 5 per cent annually. Yet for vitally important economic reasons, which we have not space to discuss here, every manufacturer strives to expand his output as steadily and as rapidly as possible.

Here there is a link between inter-commodity competition and that bogey of modern industry, overproduction. In the economic sense, overproduction does not mean the production of more commodities than people can use but rather the production of larger quantities than the market can absorb at a profit to all the producers. The standard recommendation for a manufacturer faced with general overproduction or slow growth due to operating in a closed market is diversification and the development of new products. This is possible to a certain extent in any industry; for example General Motors' entrance into the radio manufacturing field. But it is exceptionally easy in the chemical industry, because of the similarity in the scientific, technical, and even merchandising problems connected with its different products. This is at once a blessing and a handicap, for it accentuates inter-commodity competition.

There was a certain amount of this competition before, but the struggle of all companies to grow and expand during the past decade coupled with the greatly increased synthetic ability of modern chemistry, has made the matter of prime importance to all connected with the industry. For the post-war period has seen a gigantic increase in the facilities for production, and especially in the scope and flexibility of methods of producing old or new products synthetically. The contradiction resulting from the struggle to grow in the face of limited or only slowly increasing markets, and the immense ability to produce, is the major reason for the growing importance of inter-commodity competition at the present time.

The scientific research laboratory is a tool of both offense and defense in the higher strategy of inter-commodity competition. It serves its firm in opening up new fields and in guarding against attack in old ones. This is recognized by some of the more progressive companies. It has become so much of a fad nowadays to maintain a research laboratory, however, that the mere ownership of one cannot be considered to guarantee in any way that sound scientific and economic policies are being followed. Unsound programs, resulting either from the research director's unfamiliarity with economics or from the executive officers' lack of knowledge of chemistry, have definitely contributed to inter-commodity competition and overproduction in certain fields. This was excellently exemplified in the lacquer solvents industry, where the initial success of one firm led to the development of new competing products of every kind and variety by other companies. In view of the natural limitations of the market, this eventually reacted to the disadvantage of all concerned, although it furnished the student with classic examples of inter-commodity competition! In the present era, if economic planning and guidance is absent, a research laboratory may fail in its function and occasionally prove to be useless or even a boomerang.

One of the most important purposes of a research laboratory is to make possible that growth which comes from the development of products and processes that fill completely new needs. It is without doubt in this field that the greatest successes of the future will occur, and inter-commodity competition may be less serious if research programs lay more emphasis on it.

AGRICULTURE is likely to prove a more and more attractive outlet for the chemical industry in the future. At present it is frequently overlooked or its importance minimized, because of the many obstacles to be overcome, yet it is potentially the largest market for chemicals that has not been thoroughly exploited. The present agrarian crisis is having a slow but sure effect in killing off the backward, small-scale agricultural producers and strengthening the hold of the larger modern farms. This should gradually make it easier to introduce concentrated fertilizers based on phosphoric acid and synthetic nitrogen products, and improved insecticides.

Chemical developments that potentially are not so limited in scope as, for instance, the inter-commodity struggle between certain lacquer solvents, are the use of the various new and old synthetic resins as special-purpose structural materials and the use of diphenyl. The latter exemplifies particularly well the development of a product to fill new needs (heat transfer, and power generation in a binary cycle boiler) rather than to take a share of the market away from some already existing chemical.

On the whole, an economic analysis leads us to the conclusion that inter-commodity competition is with us to stay, and indeed that it is likely to become more rather than less important with the passage of time. The chemical manufacturer's only defense is a well-conducted scientific research program, in turn guided by economic research and market studies, in a continual effort to develop new uses for old products and to find new products that open up completely new fields.

Commercial Research

A safe guide through the shoals of inter-commodity competition

By Lynn A. Watt
Manager, Development Department
Monsanto Chemical Works
St. Louis, Mo.

COMMERCIAL research and market analysis are important factors in the direction and control of inter-commodity competition. They are valuable for making the most of what one has, as well as guiding the way for expansion.

Commercial research is used extensively by the larger banks and investment trusts, as well as by corporations. Substantial firms of chemical engineers have grown up to supply technical and sales reports, particularly to the former groups. The tendency among the larger units, as well as of manufacturers, is to establish separate departments for commercial research.

Such a department may be compared with a beacon light, for although organized primarily for indicating a logical and proper course of procedure, the number of unfavorable reports due to research, is large. These point out shoals, rocks, or "jokers" in the form of process weaknesses, unreliable raw material supplies, unfavorable freight rates, declining consumption, or a poor competitive position.

Essential Factors

The corporation executive has a predominantly positive viewpoint. He is interested in profits for his stockholders and favorable reports are obviously the most interesting to him. Along with the investment banker, however, the executive recognizes that the negative report is insurance against losses. Ofttimes thousands of dollars are lost more readily than made and even one ill-advised expansion or acquisition may offset the gain derived from several profitable ones.

Questions placed before a commercial research department come from every possible source within and without the organization served. Usually, they can be boiled down to the simple form: "Why don't we make——?"—let us say ethyl alcohol. And, in an equally simple form the answer is: "Why should we?" Such an answer is rhetorical and implies that before a capital expenditure can be recommended, we must visualize an attractive return on the necessary investment.

Using ethyl alcohol as a hypothetical case, one would evaluate the factors:

1. Fermentation versus synthetic processes.
2. Respective raw materials.
3. Size of plant to supply one's own requirements plus an available market (determined by survey).
4. Cost of production versus current prices and the probable averages over a five-year or ten-year period.
5. Competition with existing manufacturers and with other products.
6. The patent situation.

All of this leads up to "the estimated annual return on capital."

Proposed expansions vie with each other and, essential factors being equal, the manufacturer must invariably favor that expansion yielding the greatest return on the capital invested. The chances of favorable action on the proposed building of an alcohol plant, therefore, may be reduced by this competition.

Twenty years' experience in control, research, production, and sales is the background from which Mr. Watt writes this article. Following graduation from the University of Illinois in 1910 he served until 1919 with Armour & Company, resigning as assistant chief chemist to take charge of the control and service laboratories of the Monsanto company. Three years later he was appointed technical advisor, and from 1927 to 1929 he was a divisional sales manager. In his present position he combines technical, economic, and market studies in the solution of the problems of industrial development.

Contrasted with the suggested manufacture of alcohol, let us take another hypothetical case, the observation of the research laboratory that an exceptionally light colored resin may be made from byproduct material of which there is a considerable stock awaiting an outlet. What can be done with this laboratory product? Why shouldn't we go into the manufacture of resins?

1. There is no alternative process known.
2. Raw materials are available, and at a reasonably uniform price.
3. Plant expansion is minimized.
4. By altering conditions, the present byproduct material may be produced as a principal product with excellent yields and in any quantity which may be required.
5. Competitive position is favorable.
6. The demand for high-grade resins is increasing.
7. Tests in the application laboratory indicate compatibility with both cellulose acetate and cellulose nitrate; a rather unusual situation.
8. No unfavorable patent situation exists.

The tie-up with current operations is desirable and the various factors are uniformly favorable.

The rayon, celluloid, transparent sheeting, laminated glass, and special lacquer formulation, all represent potential fields for application. Success in each probably will not be attained, but the field is broad enough to justify favorable action. Investment in plant equipment and supplemental research is obviously indicated.

Analysis Lessens Speculation

Most questions coming before a commercial research department refer to new items or new products; at least they are new to those to whom they are referred. That is not a disadvantage, for it means taking up the necessary investigation, first in elementary fashion and growing up with it, so to speak, until, having acquired all available information from the literature and perhaps outside consultation, plus the

results of original research work, one becomes for the time being something of an authority on that particular subject. He must visualize the proposal as a going concern. From raw materials to the application of the finished product, he must see each step as if in actual operation.

Commercial research and market analysis lessen materially the speculative element in business. We see around us many successful articles, the manufacture of which was started without any survey of available markets and perhaps with a relatively incompleted process.

Research Procedures

Eliminating the element of good fortune, which applies to few cases, the success of these items must be attributed to an expanding market or to the foresight of some one individual. Without the necessity of detailing his observations, he was, nevertheless, well posted and shouldered the responsibility for the initial move. In effect, therefore, such a man in a small organization may cover the field of commercial research and market analysis.

Most corporations must consider this work of sufficient importance to justify the appointment of a capable director for this type of research. One of the outstandingly successful chemical groups in America has had such a department for more than 30 years. Its existence has been amply justified.

Many commercial research problems have their inception in the necessity for the disposition of byproducts. This is often more desirable than expanding in directions not related to current operations and tends toward better co-ordination.

Other problems are designed for the rehabilitation of markets which are declining. Third, there is the constant desire to expand outlets for existing products.

For these three types of problems, different procedures are followed:

1. Simple announcement through trade papers that a given material is available. Usually there is some suggestion as to the fields in which it may be applicable, but no data or service is offered. It is entirely up to the potential consumer to take the material and work out an application for it, independently and at his own expense.

2. With the establishing of specialized research departments operated by corporations directly, and also through industrial fellowships, processes of manufacture are not only worked out but methods for applying the finished product or using it as an intermediate are developed. This is a complete service to the consuming trade. It is expensive from the economic viewpoint, but probably less so than if the ultimate goal resulted from a large number of independent and duplicating investigations by potential consumers.

The principle of this complete service is growing. It is accelerated by such mediums as Mellon Institute, the Crop Protection Institute, and the opportunity to establish fellowships under the direction of outstanding men at practically any of our universities.

The third procedure is an intermediate one, namely, the conducting of sufficient research to demonstrate the possibility of an application, but leaving the working out of a complete process to the purchaser's own staff. Wherein the application may be a highly specialized one and detailed information closely held, such as in the rayon industry, for example, this procedure has its advantages. It has the disadvantage from the chemical manufacturers' viewpoint that the application of his product may be controlled through patent by his customer and his market thereby limited.

The chemical manufacturer must, therefore, decide cases as they arise on their individual merits as to whether he shall risk an investment on a completely worked out application, or take an intermediate position. It is seldom today that the bare announcement without any ability to render service with respect to the use of a product will lead to success within a reasonable time.

Another type of problem, having no direct bearing on sales, has to do with raw materials. To manufacture successfully, these must be available competitively. Situations frequently arise in which consideration must be given to the manufacture of intermediates to insure a competitive manufacturing position. This leads to comprehensive studies of domestic and international positions, and the picture may be complicated by the necessity for disposing of isomeric byproducts. Commercial research in this respect is closely associated with both purchasing and sales.

Markets for Any Products

Byproducts which are potentially main products are a part of current as well as ancient history in the chemical industry. Practically every manufacturer is confronted with the disposition of isomeric or unavoidable byproducts. It can be stated almost categorically that if sufficient and concentrated effort is put behind an idea, a profitable market can be found for almost any product. If it cannot be used "as is," there is something which can be made from it which will be marketable at a profit. This statement must be qualified, of course, with the requirement that the byproduct either be produced as such in sufficient quantity or be capable of production as a principal product to assure success. There is nothing more distressing than to work up an outlet for a byproduct, only to find that the limited quantity available prevents the development of a profitable market for it.

Given this consideration of essential and unlimited supply of a byproduct its disposition becomes one of the most attractive of all problems confronting those interested in commercial research. With a minimum capital investment, but ofttimes a considerable one in research, a contribution to the success of one's principles frequently is made. In this, as well as other phases of the work coming under the head of commercial research and market analysis, a very close working agreement must be maintained with the research, patent, and manufacturing departments. The academic viewpoint must be observed, but along with it the ability to interpret practical manufacturing conditions and the problems of the sales manager.

✦

Domestic Production of Acids, 1927-1929

	1929	1927
Total value	$96,710,078	$88,175,519
Acetic:		
Dilute, basis 100 per cent—		
Total production, pounds	72,430,797	*41,399,599
Made and consumed in the same establishments, pounds	19,525,990	*10,918,361
For sale—		
Pounds	52,904,807	*30,481,238
Value	$5,487,427	*$3,522,196
Glacial—		
Pounds	13,349,259	*15,815,347
Value	$1,402,984	*$1,527,089
Boric (boracic):		
Pounds	23,243,662	21,009,603
Value	$1,452,893	$1,582,565
Carbonic (carbon dioxide CO_2):		
Pounds	†114,471,121	74,344,287
Value	†$6,637,349	$6,048,424
Chromic:		
Pounds	3,612,980	898,093
Value	$614,492	$241,965
Citric:		
Pounds	10,697,660	7,058,215
Value	$4,807,984	$3,150,976
Hydrochloric (muriatic):		
Total production, tons	254,986	224,596
Made and consumed in the same establishments, tons	61,479	62,154
For sale—		
Tons	193,507	162,442
Value	$3,108,712	$3,016,014
Production according to strength, tons—		
20 deg. Baumé	213,675	193,364
18 deg. Baumé	17,843	26,803
Other strengths and strengths not specified	23,468	4,429
Hydrofluoric:		
Pounds	7,375,096	6,675,288
Value	$561,283	$614,125
Mixed (sulphuric and nitric):		
Tons	56,521	60,625
Value	$3,869,434	$3,820,564
Nitric:		
Total production, tons	156,313	121,991
Made and consumed in the same establishments, tons	122,477	93,285
For sale—		
Tons	33,836	28,706
Value	$3,294,365	$3,559,436
Phosphoric:		
Pounds	29,895,470	22,397,366
Value	$1,988,573	$1,681,504
Sulphuric, basis 50 deg. Baumé:		
Total production, tons	8,364,034	7,335,795
Made and consumed in same establishments, tons	2,410,551	2,364,212
For sale—		
Tons	5,953,483	4,971,583
Value	$44,894,622	$42,885,573
Tannic:		
Pounds	1,449,375	1,297,232
Value	$503,567	$593,465
Tartaric:		
Pounds	5,906,479	5,781,166
Value	$2,059,680	$1,810,890
Other acids, value	$4,055,873	$4,431,493

*Revised.

†Revised; originally published, under date of Nov. 6, 1930, as 88,186,356 lb., valued at $6,280,647. Includes data for carbon dioxide used as a material in the manufacture of "dry ice" (solidified carbon dioxide) in the same plant in which produced or in other plants.

From U. S. Census of Manufactures, 1929

Watching the World for New Factors In Commodity Competition

By C. C. Concannon and T. W. Delahanty

Chemical Division,
U. S. Bureau of Foreign and Domestic Commerce

COMPETITION is the motivating spirit which vitalizes trade, industry, and commerce. Development of means of communication and of transportation has eradicated many international factors which were of paramount importance up to a few years ago. While the world has been growing relatively smaller, the importance of commerce has been growing in the economic scheme of things. Today there is no undertaking so isolated or provincial, nor any individual so detached or parochial, that it is not affected in some way by world developments, be the theater of operations in Europe or South America or even in the Antipodes.

What is the character and significance of the international factors in commodity competition? These may be divided into two main groups. On the one hand arises actual competition based upon inherent properties of material or circumstances of the situation, and on the other hand competitive conditions due to artificial legal or legislative measures, which might be subdivided as follows:

(1) Character of market—size, customs, standards of living, education, and buying power of the masses; (2) business facilities—transportation, banking, distribution agencies, and trade practices; (3) raw material situation, inclusive of labor and energy; (4) degree of government co-operation — subsidy, tariff, regulations, patents, and enabling or restraining legislation; and (5) extent of scientific and technological progress.

Chemical Cross-Currents

The fiat factors of international competition involving tariffs, restrictions, cartels, subsidies, and an almost unending series of helps or hindrances, depending upon the point of view, are extremely important and are sometimes a completely controlling consideration. It is sufficient at this time to refer in passing to the importance of political, pseudo-political, and politico-economic considerations in international competition in the chemical field.

The competition of which we speak is a variegated picture, the principal components of which are products, processes, and uses. Thus we may discover new sources of raw materials; we may develop new uses for already existing products; or we may revolutionize an industry through a change in technique. And be it noted that the chemical industry is continuously and everlastingly in a rapid state of flux with all the factors of competition exerting their influence throughout the entire world.

Indigo serves as an example of a natural agricultural material which suffered from competition with the synthetic coal-tar product. Today, natural indigo is practically unheard of. Camphor is an essential raw material in the manufacture of pyroxylin plastics and we have been for many years dependent upon Japan for our supplies, but recently synthetic camphor of German origin has begun to replace the natural substance. Camphor is synthesized from turpentine derived from the pine trees of our Southern states, and the next logical step is to establish our own domestic synthetic camphor industry.

Removal of bromine impurities from a salt brine halted a German monopoly and so stimulated further research that one of the most unusual chemical industries in the world was built around a brine well. Development of American potash brines helped to relieve the farmer of dependence on the Franco-German potash monopoly, and byproduct borax has set up severe competition for the British borax monopoly.

American supplies of glycerine had seemingly never been adequate, so that the explosives manufacturer was to some degree dependent upon a British syndicate for raw materials. When the soap-maker introduced glycerine into the anti-freeze field, a supply and price situation ensued which not only paved the way for synthetic ethylene glycol but offered an opening to synthetic glycerine prepared from the fermentation of molasses slop from ethyl alcohol production. All these products together with synthetic methyl alcohol, evolved as a byproduct in the fixation of nitrogen, are now competing with one another in many ways, particularly in the anti-freeze field. Synthetic nitrogen, aside from affecting the nitrate and byproduct ammonia industries, has brought about a reduction of salt-cake production, which seems to offer an induce-

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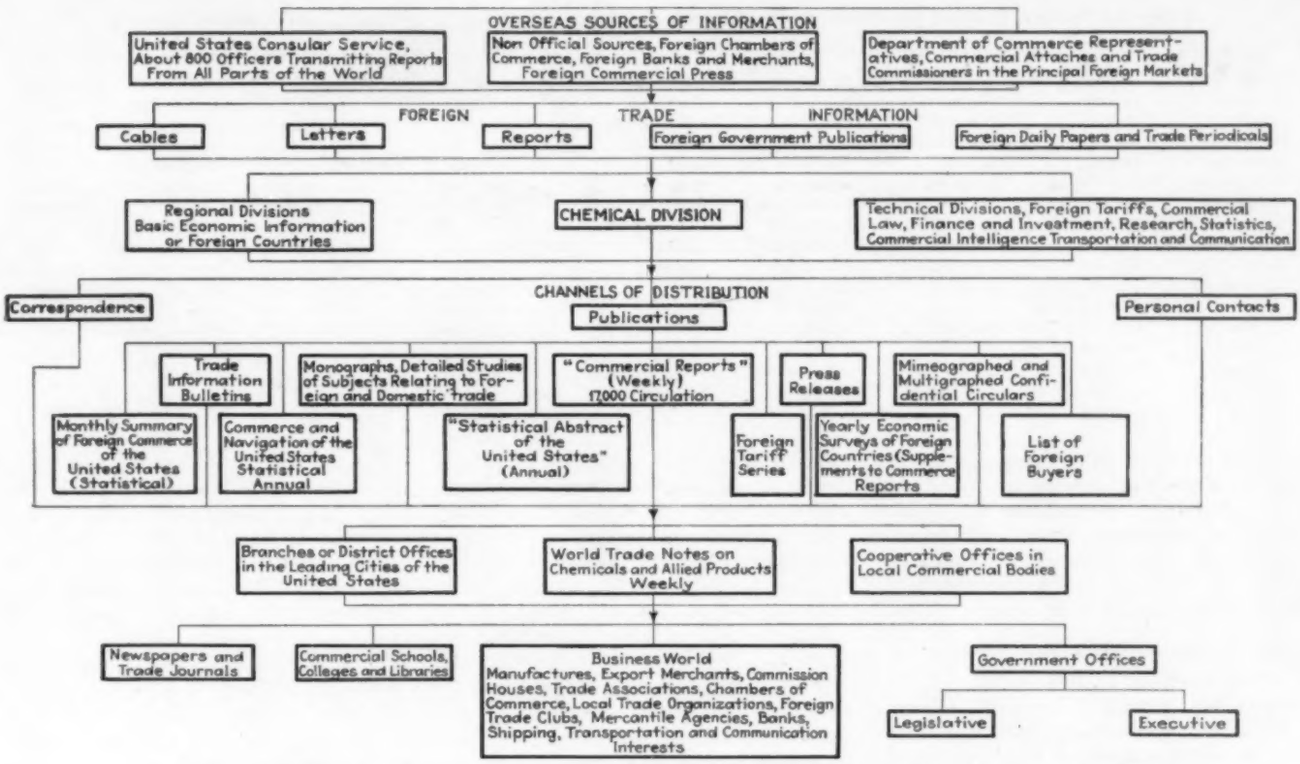
"ANTICIPATION of approaching events is perhaps the greatest present need of the chemical industry and the outstanding type of service which the Chemical Division of the Bureau of Foreign and Domestic Commerce is called upon to render, made necessary by the increasingly important rôle which the science of chemistry is playing in every line of industrial activity. Synthetic products are being developed to replace natural products at so rapid a pace that unpleasant economic consequences can easily overtake established commercial enterprises if the trend is not foreseen and properly appraised."

Robert P. Lamont,
Secretary of Commerce.


OVERSEAS SOURCES OF INFORMATION
United States Consular Service, About 800 Officers Transmitting Reports From All Parts of the World
Non Official Sources, Foreign Chambers of Commerce, Foreign Banks and Merchants, Foreign Commercial Press
Department of Commerce Representatives, Commercial Attaches and Trade Commissioners in the Principal Foreign Markets
FOREIGN TRADE INFORMATION
Cables
Letters
Reports
Foreign Government Publications
Foreign Daily Papers and Trade Periodicals
Regional Divisions Basic Economic Information on Foreign Countries
CHEMICAL DIVISION
Technical Divisions, Foreign Tariffs, Commercial Law, Finance and Investment, Research, Statistics, Commercial Intelligence Transportation and Communication
CHANNELS OF DISTRIBUTION
Correspondence
Publications
Personal Contacts
Trade Information Bulletins
Monographs, Detailed Studies of Subjects Relating to Foreign and Domestic Trade
"Commercial Reports" (Weekly) 17,000 Circulation
Press Releases
Mimeographed and Multigraphed Confidential Circulars
Monthly Summary of Foreign Commerce of the United States (Statistical)
Commerce and Navigation of the United States Statistical Annual
"Statistical Abstract of the United States" (Annual)
Foreign Tariff Series
Yearly Economic Surveys of Foreign Countries (Supplements to Commerce Reports
List of Foreign Buyers
Branches or District Offices in the Leading Cities of the United States
World Trade Notes on Chemicals and Allied Products Weekly
Cooperative Offices in Local Commercial Bodies
Newspapers and Trade Journals
Commercial Schools, Colleges and Libraries
Business World
Manufactures, Export Merchants, Commission Houses, Trade Associations, Chambers of Commerce, Local Trade Organizations, Foreign Trade Clubs, Mercantile Agencies, Banks, Shipping, Transportation and Communication Interests
Government Offices
Legislative
Executive

How Chemical Division Serves Industry as Focal Point Between Information Sources and Media

ment to the German producer. Our largest growing export market for phosphate rock is Germany, and one of the largest chemical firms in that country is now co-operating with one of our Florida phosphate factors in the building of an American plant designed to produce for export elemental phosphorus in place of phosphate rock, a development probably as revolutionary as the fixation of nitrogen.

Immigrating Ideas

Sometimes the possibilities of a development are not fully appreciated in the country of issue. Such was the case with acetone, worked out abroad on a fermentation basis to meet an emergency, translated to this country, temporarily disposed of as uneconomic, but rejuvenated through the byproduct butyl alcohol which revolutionized the paint industry of the world. Utilization of one byproduct in this industry led to others—methanol evolved by fixing the waste gases of fermentation, excess CO_2 disposed of for the production of "Dry-Ice," byproduct ethyl alcohol oxidized to acetic acid—in the summation a blow to the domestic wood distillation industry, which had just received tariff relief from German synthetic methanol and was still suffering from competition of synthetic acetic acid produced from acetylene.

This reference brings to mind a splendid illustration of the competitive effect of new raw materials and new processes upon international trade. Prior to 1924 the United States was the principal world supplier of calcium acetate, acetone, and methanol. From that time on, through the advent of synthetic derivatives abroad, our exports of these products disappeared. The acetate is still absent from our recorded exports. Acetone, however, has now become active again, due to progress of the American butyl alcohol producers, and methanol similarly through them and the fixed nitrogen producers. Likewise, there are indications that synthetic acetic acid may be disposed of abroad to meet the former demand for calcium acetate. Furthermore, products derived from these synthetics are daily being exported in increasing volume.

With butyl alcohol as a striking illustration in the field of bacteriology we now find our chemists at work producing other organic alcohols, aldehydes, ketones, acids, and the like, designed to relieve the country from dependence upon foreign sources of these products. And in this connection, the Italian citrus fruit producer now feels the loss of his American citric acid market as much as the German lactic acid producer—now supplied synthetically.

These sketchy illustrations are designed not only for the purpose of indicating the factors which influence intensive and extensive competition of raw materials, or wherein one new product replaces another or a natural product encounters the synthetic evolute of fixation or fermentation, but more particularly to focus attention on their international character and to impress upon the American chemical industrialist the necessity of developing a world chemical consciousness.

At one time we supplied the world with pine tree distillates, turpentine and rosin; now France and others are competitors. Hardwood distillate sales abroad have given way to synthetics. Phosphate rock from Northern Africa has relegated the United States to second place in the same manner that Louisiana and Texas sulphur displaced Italian sulphur and Spanish pyrites. Chilean nitrate and coal byproduct ammonia now face the aggressive synthetic nitrogen products. Tung oil from China awakens the American paint and linseed oil producers, and subsequently China will find that American agricultural efficiency can meet our growing demand for this exotic essential raw material.

No nation can long lay claim to a monopoly, either as to materials or processes. The time has passed when the world looks to Chile for nitrate, or to Japan for camphor, or believes Germany to be a chemical super power, or wishes for the cheap manpower of the Orient, or even envies the bounteous natural resources of the United States.

Promoting American Products

President Hoover, when Secretary of Commerce, was one of the first Americans to recognize the situation. To him credit must be accorded for foresight, action, and support in remodeling and developing the Bureau of Foreign and Domestic Commerce, which, under the able directorship of Dr. Julius Klein, at present Assistant Secretary of Commerce, rose to an exalted position as a constructive agency serving the interests of American business. To promote the sale of American-made products throughout the world is the function of this Bureau, and of equal importance

Table I—Service Contact Facilities of the Chemical Division, Bureau of Foreign and Domestic Commerce

District and Co-operative Offices					Foreign Offices			
Akron	Columbus, Ga.	Jacksonville	New York	San Antonio	Acra	Calcutta	Melbourne	Santiago
Anniston	Columbus, O.	Kansas City	Norfolk	San Diego	Athens	Caracas	Mexico City	Sao Paulo
Atlanta	Dallas	Keokuk	Oakland	San Francisco	Bangkok	Copenhagen	Milan	Shanghai
Baltimore	Dayton	Lake Charles	Omaha	Seattle	Barcelona	Guatemala City	Montevideo	Singapore
Beaumont	Denver	Laredo	Oklahoma City	South Bend	Batavia	Habana	Montreal	Stockholm
Binghamton	Des Moines	Longview	Pensacola	Spokane	Belgrade	The Hague	Mukden	Sydney
Birmingham	Detroit	Los Angeles	Philadelphia	Syracuse	Berlin	Helsingfors	Oslo	Tientsin
Boston	El Paso	Louisville	Pittsburgh	Tacoma	Berne	Hong Kong	Ottawa	Tokyo
Bridgeport	Erie	Lowell	Portland	Tampa	Bogota	Istambul	Panama	Toronto
Buffalo	Fort Smith	Memphis	Providence	Toledo	Bombay	Johannesburg	Paris	Vancouver
Charleston	Fort Worth	Milwaukee	Rochester	Tulsa	Brussels	Lima	Prague	Vienna
Charlotte	Galveston	Minneapolis	Raleigh	Trenton	Bucharest	Lisbon	Riga	Warsaw
Chattanooga	Greensboro	Mobile	Richmond	Waterbury	Budapest	London	Rio de Janeiro	Wellington
Chicago	Hartford	Newark	Rockford	Wichita	Buenos Aires	Madrid	Rome	Winnipeg
Cincinnati	Houston	New Haven	Salt Lake City	Wilmington	Cairo	Manila	San Juan	
Cleveland	Indianapolis	New Orleans	St. Louis	Worcester				

and at times of even more significance is the reporting service which collects and distributes information of a competitive character: New products, new processes, and changing conditions which may affect the American chemical industry both at home and abroad.

Function of Chemical Division

The Director of the Bureau of Foreign and Domestic Commerce, William L. Cooper, has touched upon this theme in speaking about the activities of the Chemical Division: "Because of this necessity for keeping abreast of the march of events abroad as well as at home, one of the principal services of the chemical division has been the supplying of information relative to competitive activities throughout the world, but especially in Europe. A steady flow of technical and commercial news of this character has been released in the form of weekly issues of World Trade Notes on Chemicals and Allied Products, more than 2,000 separate references to trade conditions having thus been published during the past year.

"Further to anticipate the need for fundamental data, comprehensive surveys on paints and varnishes, polishes, toilet preparations, prepared medicines, dental preparations, veterinary products, essential oils, and explosives were issued as special mimeographed circulars. Domestic industry benefited greatly through these activities by being kept fully advised of developments in similar fields abroad. At the same time, the feature of foreign trade promotion was stressed, with the result that overseas shipments of staples have been maintained and markets for many new products have been found."

Economic Information

Statistics and reports from commercial attachés, trade commissioners, and consuls, all manner of commercial and trade data, are the tools with which the Chemical Division works. The statistical services available through the division are many in number and varied in scope, and they all carry their pointed message and bear directly on competition. Certain statistics show the quantity and value of detailed imports in the chemical field. Not all imports are competitive products, but import statistics are frequently given in sufficient detail to portray graphically the character and extent of the competition which domestic manufacturers are facing in given instances. In fact, statistics of all kinds—alas! too infrequently consulted, or even if consulted, not properly appraised—carry a message which more often than not depicts the rivalry of products or portrays trends arising from competitive situations.

How the Chemical Division serves American industry is shown in Table I and the preceding chart. In one instance the Chemical Division appears as the central point with the many foreign offices of the Bureau on the one hand, and counterbalanced on the other hand are the various domestic branch offices throughout the United States. In the other representation is shown the organization layout of the Bureau of Foreign and Domestic Commerce functioning through the Chemical Division as a service medium.

Necessity of Foreign Markets

It should not seem necessary at this stage of our growth as a world power to stress the absolute necessity for a well-developed and ever-increasing foreign business. The difference between success and failure is frequently measured by the margin of goods shipped abroad. The figures in Table II proclaim better than words can tell the magnitude and significance of our chemical trade with the rest of the world.

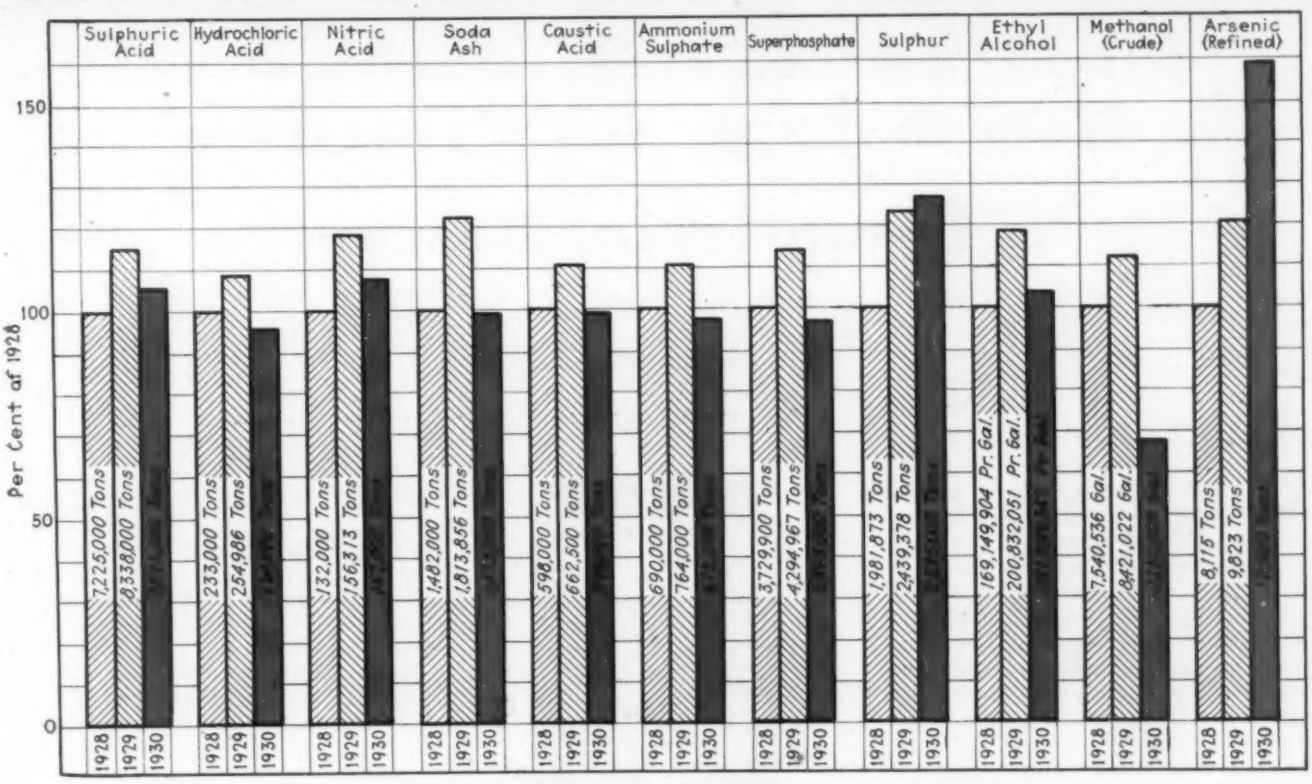
Present world-wide business distress no doubt is due in large measure to the blind folly of imagining a condition of affairs actually non-existent. Research in the field of production has perfected that phase of our commercial life to such an extent that production has today far outstripped distribution. Herein lies one of our greatest industrial and economic problems. The value of scientific research has amply proved its worth in production, but the research which we sadly lack and which we must develop and make use of in the future is commercial research. International factors in commodity competition will then become common indices of ordinary business. This will help us solve our distribution difficulties, and the recurrent business depressions to which we have been subjected will be at least greatly ameliorated.

Table II—Chemical Exports of Five Major Countries, 1926 and 1929

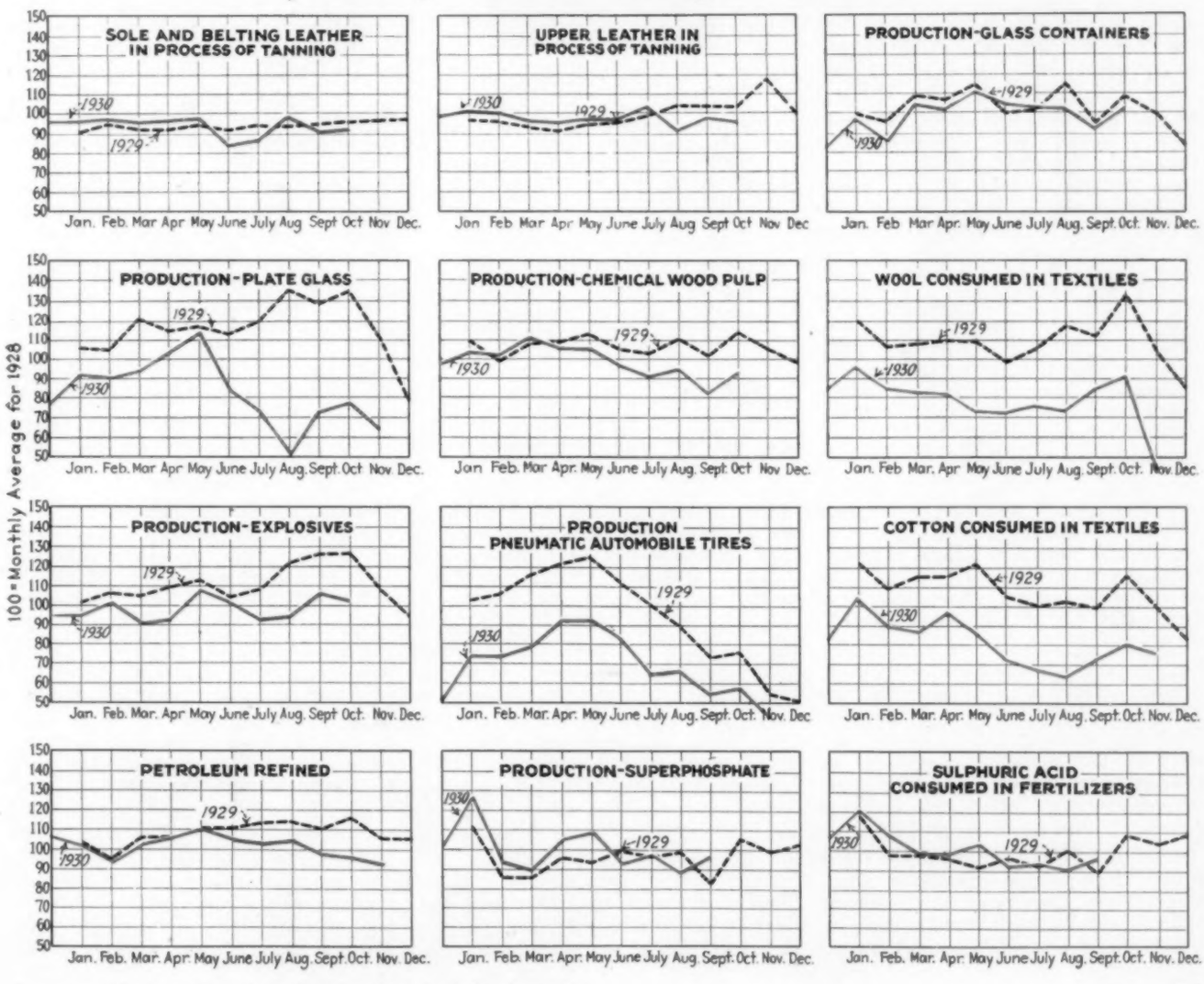
(In Thousands of Dollars)

	United States	Germany	United Kingdom	France	Italy
1929					
Coal tar products	18,180	61,973	17,746	6,227	996
Industrial chemicals, including Sulphur	61,970	96,895	50,641	36,269	17,658
Fertiliser Materials	25,747	102,139	30,990	28,150	1,424
Explosives, matches and pyroxylin	6,549	10,817	7,700	544	1,286
Paints, pigments and naval stores	62,694	33,735	26,741	13,264	1,697
Medicinal and toilet prep'tions	33,120	35,037	22,530	44,624	3,998
Essential oils, crude drugs, etc.	6,640	6,062	6,698	7,440	10,104
Total chemicals	$214,900	$346,658	$163,046	$136,518	$37,163
1926					
Coal tar products	14,093	58,229	16,323	8,21[illegible]	682
Industrial chemicals, including Sulphur	39,761	67,792	47,515	31,901	8,420
Fertiliser Materials	20,500	66,402	14,394	15,235	765
Explosives, matches and pyroxylin	7,251	7,768	4,712	1,528	927
Paints, pigments and naval stores	55,752	23,659	22,104	16,672	1,427
Medicinal and toilet prep'tions	28,082	28,676	20,477	32,682	3,200
Essential oils, crude drugs, etc.	5,866	3,524		7,996	8,015
Total chemicals	$171,305	$256,050	$125,526	$114,225	$27,370

CHEM. & MET. Estimates of OUTPUT of BASIC CHEMICALS



Activity in Consuming Industries



How to Apply the Principles Of Commercial Research

By Bethune G. Klugh

Vice-President, Swann Chemical Company
Birmingham, Ala.

SUCCESS or failure for a number of chemical enterprises, in this decade, will be determined, in a large measure, through the effects of inter-commodity competition. Therefore the business and industrial leader of today must have dependable, precise, and expedient information relating to every phase and activity bearing directly and indirectly, actually and potentially, upon his field of operations. In the present dynamic state of chemical industry the influences of inter-commodity, inter-process and inter-industry competition upon a particular operation may appear far-reaching and far-fetched, yet they are subject to analysis and interpretation under proper systematic study and procedure. An effective agency through which these influences may be constructively co-ordinated is commercial research, regardless of the name or departmental function under which it serves.

Commercial research, adequately equipped, properly conducted, and correctly co-ordinated with the other organization functions, can guide and direct its industry constructively into profitable channels where obtainable and can avoid destructive and unsound competitive lines of business where imminent.

In serving any specific industry, enterprise, or operation for the exigencies of this newer, more serious, and vital form of competition, the individual or organization functioning in commercial research follows substantially the same course for offensive as for defensive action. This service consists primarily of assembling and co-ordinating knowledge covering statistics, operations, methods, markets, costs, prices, trends, etc., relating to any given commodity, process, or product. Such data apply with equal importance, whether the confronting problem be finding markets for new products; developing new outlets for existing products; investigating and forecasting sources of competition in existing projected or proposed business lines; determining the course for meeting present or impending competition; or developing a product for a determined market. The complete report is necessary to answer correctly the questions that involve any of the foregoing cases.

Few chemical engineers have combined technology and economics on a more practical basis than B. G. Klugh, who since 1926 has been vice-president of Federal Phosphorus Company, and its successor, the Swann Chemical Company. From 1920 to 1926 he served as secretary and chemical engineer for the American Ore Reclamation Company. As vice-president in charge of commercial research for Swann Research, Inc., he has had an unusual opportunity to apply the principles and methods outlined in this article.

Executive decision and action can be safely predicated upon commercial research reports only where such reports are complete and final to the date of such decision. In rare instances this research initially discovers and discloses immediate facts which may determine a final positive or negative decision for action upon the particular matter under consideration. As a rule, however, preliminary data, incomplete surveys, and fragmentary figures are likely to be misleading without the full assembly of interrelated facts resulting from an exhaustive investigation. Decision upon the basis of only part of the essential facts is as hazardous as that upon "hunches" or "intuition."

There are certain potential and intangible elements of inter-process and inter-product competition that commercial research cannot forecast accurately or definitely regardless of the competence, thoroughness, or energy of the personnel conducting the investigation. Examples of this class lie in organic chemicals, all of which are subject to possible synthesis from cheap raw materials and to low conversion costs through technical research, and in alloys the properties of which are not predeterminable in the present state of applied science. However, a commercial research survey can chart the determinable fields of potential competition and evaluate the probabilities from doubtful areas. With this incorporation of the complete survey, the measure of the extent and influence of these considered forms of competition for any specific industry or product will be provided, by which the policy of attack can be rationally determined.

The plans upon which a commercial research investigation will be best conducted will suggest and automatically arrange themselves, once the work is organized and in progress. Particular products or process problems require specific systems of survey. The following outline of procedure is suggested as covering the general plan.

Results of such a classification of detail data might be summarized into the fundamental principle that any business is sound only so long as it best serves the interests of its customer, according to available means. The consuming industry changes its commodity requirements only for economic advantage. This particular economy may be directly in first cost, indirectly in processing cost, or in changing demands of the ultimate product. The producing industry can, in a large measure, protect itself, investors, and personnel from the potentially destructive force of product displacement through cognizance of the changing conditions bearing upon its own field of operations and that of consuming fields. It may, through the agency of commercial research along the above applied lines, forecast the inevitable decrease in consumption of its products in time to retrench without serious loss, and to direct its activities into other and more profitable channels.

A Working Outline for Commercial Research

(A) Description of Products
- (1) Chemical Properties
  Including acidity, alkalinity, solubility, derivatives, etc.
- (2) Physical Properties
  Including specific gravity, thermal and electrical characteristics, forms, etc.

(B) Process of Manufacture or Preparation
- (1) Flow sheet showing steps in production of existing process.
- (2) Flow sheet showing steps in competitive process—comparatively arranged with (1).
- (3) Equipment Required
  - (a) Comparison of equipment for existing, competitive and potential processes.
  - (b) Materials of construction in existing and competitive processes, with statement of potentially more economic sources.

(C) Raw Materials
- (1) Sources, qualities, specifications, and relative costs of all raw materials of existing process.
- (2) Same data as (1) for competitive process.
- (3) Other potentially available raw materials possible of filling needs, and relative costs.
- (4) Statistical data showing range and trend of prices, production, and consumption of each raw material involved.
- (5) Other uses of these raw materials with indication of increased use exhausting supply or increasing prices.

(D) Production and Consumption Data
- (1) List of domestic producers with available figures of relative position in industry.
- (2) Domestic Production
  - (a) Statistical data over period of years showing trends.
  - (b) Proportion of product consumed by the producers or marketed.
  - (c) Sectional distribution of production.
- (3) Domestic Consumption
  - (a) Statistical data over period of years showing trends.
  - (b) Sectional distribution of consumption.
- (4) Foreign Production
  Available statistics of production in foreign countries.
- (5) Foreign Consumption
  Available statistics of consumption in foreign countries.

(E) Imports and Exports
- (1) Statistical data of imports by countries for period of years.
- (2) Statistical data of exports by countries for period of years.
- (3) Tariff
  - (a) United States and foreign countries over periods of change.
  - (b) Classification influencing duties of various forms or types of product.

(F) Production Costs
- (1) Comparative estimate and statements of existing and competitive production costs—including and classifying:
  - (a) Investment costs—covering interest on invested capital, working capital, inventories of raw materials and product stages, amortization.
  - (b) Overhead, administrative and sales costs.
  - (c) Raw materials, at source.
  - (d) Freight, inbound and outbound.
  - (e) Conversion costs.
- (2) Comparative costs estimates for numerous processes and locations.
- (3) Comparative cost estimate with increment correction for numerous rates of production.

(G) Prices
- (1) Statistical data showing prices of several forms and grades over period of years with trends.
- (2) Statement of conditions influencing price changes past, present and potential future.

(H) Uses
- (1) List of consuming industries and agencies, with quantities, grades, forms, locations, etc.
- (2) List of consuming purposes with quantities of each as far as available.
- (3) Characteristics of product determining its selection and use in each industry, purpose, and service.
- (4) Estimated quantities and proportions of product:
  - (a) Consumed in process industries losing its identity and irrecoverable as such.
  - (b) Remarketed in mixtures, under trade names or otherwise retaining identity in resold product to ultimate consumer.
  - (c) Utilized in process industries permitting recovery in relatively valuable form for replacing original product.

(I) Byproducts and Coproducts
- (1) List and quantities of byproducts and coproducts, in relation to main product:
  - (a) Byproducts in marketable form as produced.
  - (b) Byproducts requiring additional processing cost for marketing.
  - (c) Byproducts of doubtful status as to whether carrying credit for sale, or penalty for disposal.
  - (d) Byproducts with limited market, the excess of which restricts production of main product through impossibility of disposal or necessary credit.
- (2) Potential profits from byproducts:
  - (a) Through processes developed by research.
  - (b) Through development in consuming industries.
- (3) Market survey of each byproduct as outlined for main product.

(J) Patent Situation
- (1) List of patents bearing upon business under consideration:
  - (a) Product patents.
  - (b) Process patents.
  - (c) Apparatus patents.
  - (d) Use and application patents.
- (2) Influence of Patents Upon Business
  - (a) Expired patents definitely opening essential features.
  - (b) Valid patents conveying monopoly of features to others with evaluation of importance of such features.
  - (c) Patents under adjudication suspending status of business.
- (3) Pending Patents of Company
  - (a) Probable value of patent in business.
  - (b) Possibility of patent controversy.
- (4) Available patents through purchase or license, with estimate of cost and evaluation.

(K) Competitive Considerations
From analysis and study of foregoing data actual and potential status of competition in its various forms, phases, and relations is classified and evaluated.
- (1) Price
  - (a) Ultimate minimum price in view of possible production cost in "F."
  - (b) Influence of prices from foreign competition.
  - (c) Reduction in price necessary to extend into other consuming fields.
- (2) Quality and Service
  - (a) Preferential business existing and available through improvement in quality, packing, delivery, or other characteristics of present product.
  - (b) Deficiencies in present quality, character, purity, physical state, or other features of present products that may through modification extend it into other consuming lines.
- (3) Potential Product Competition
  - (a) Study of similar functional qualities of materials in all possible industries and check against properties of present product to possibility of new outlets.
  - (b) Study of purpose and specifications of present consumer for present product to determine possible competition from other materials. (From data of H-3.)
  - (c) Study of markets and trends of principal products consuming the material in question to determine the future outlook for such applications.

Industrial Research

Beneficent Arbiter of Modern Progress

By William A. Hamor

Assistant Director
Mellon Institute of Industrial Research
Pittsburgh, Pa.

THE poetic concept of the Fates as the arbiters of men's lives has its present-day analog in the more benign forces that direct industrial progress. They made life so unsatisfactory that the sages held no man fortunate until he had died; but the various types of scientific research, the modern Fates of industry, strive to make men more happy and prosperous.

Clotho, who, in mythology, began the thread of life by putting the wool around the spindle, is now basic production research, or the industrial research that reveals new products and new processes. Lachesis, who fixed the length, has been replaced by production research, which directs manufacturing-scale development. Instead of the gloomy Atropos, who cut the thread, we have a brighter figure, commercial research, to show men how they are wasting effort and resource on obsolete commodities and to direct their attention to those more profitable.

Applied science is the benevolent patron of industry. It seems that no object is so modest or unimportant but that the industrial scientist can find ways to improve it. By discovering new materials or new uses for known substances he satisfies unborn desires and needs. By improving processes and products he so affects the economics of production that a larger number of people can enjoy the results of his systematic work. The research laboratory is the armory of the industries: in it are kept the trophies of the past as well as the weapons for future conquests.

The creation of a new industry is the highest aim of managemental research. The economic value of such a feat is not always realized clearly. It is something more than merely making a new commercial product. It has wider consequences than the evolution of a novel process. A novel industry of importance is a development that adds a chapter to the history of social as well as technologic progress.

IN ALL RESEARCH that culminates in a new branch of manufacture, the following stages are found: (1) the scientific investigation (basic production research) that effects the new product or process; (2) production research, first on the sub-commercial scale and then on the factory scale, to determine plant, operating procedure, raw materials and their handling, and plant manufacturing costs and output; and (3) commercial or merchandising research, which has for its aim, through co-operative study by the research laboratory and the production and sales departments, the obtaining of complete information respecting present and probable future markets for the novel product or products. Hand in hand with the market analyses there must be conducted consumer tests or service trials. Then, too, the research laboratory must be constantly alert for possible new commercial applications.

THIS rather complicated program frequently requires a long period of time for successful consummation. An entire year will be devoted in many instances to consumer testing or to practical trials of a new commodity in actual service. This investigational work often leads to improvements in the product in order to make it more suitable for the requirements of commerce, and just as frequently to beneficial changes in manufacturing and merchandising plans. In addition, there is collected in these tests a considerable amount of information that will be applicable in the ensuing sales-promotion and advertising activities.

The research laboratory specialists who discovered the new product or process will have an intimately active or at least an advisory connection with the novel commodity from the time it is baptized until it has passed through its childhood day of commercialization. Close contact of these scientists with the product is often maintained throughout its commercial life, from adolescence until it is finally supplanted by a better article, as actually occurs in many cases, owing to the constant progress that is made in all industries by the proper application of science. The keynote of all this research is aggressive alertness, elimination of chance, and open-mindedness.

That the acquisition of factual information of this broad type and scope is essential in soundly good research, both industrial and commercial, is exemplified in the cases of the products of the new industries created at Mellon Institute to be described in this paper. In the instance of every new commodity of importance, novelty in commercial research comes in much the same way as it has previously occurred in the fundamental laboratory investigation. The merchandising practices that have been and are being followed in the cases of phenolic resins and chemicals from ethylene, two developments that will be narrated at length further on, constitute classics of their kind.

The spirit of scientific management characteristic of modern business originated in the philosophy of research. A product of the laboratory, it has not deserted its original home, even though it has widened its influence vastly. The increasing complexity of investigational methods, the stupendous growth of the literature of science, and the necessity for utilizing for one problem several branches of knowledge, have caused a trend toward mass organization in research.

CHANCE of success for the old-time inventor is becoming less, and the isolated researcher, even though he be well trained in science, is at a disadvantage in competition with a large organization. Mellon Institute, housing as it does specialists in many fields of technology, enjoys particular advantages in this respect.

Sixty-six industrial fellowships, each on a separate problem, are in operation at Mellon Institute at present. As soon as a study has been completed, another investigation (on a different subject, of course) is begun. The results of each research, to which the men on the fellowship devote their full time, are the property of the company or industrial association supporting the work. In many cases some or all of the information obtained is released to the scientific and general public by means of journal contributions, lectures, periodical or newspaper articles, and radio talks.

The men on the different fellowships

are available for consultation by any other member of the Institute. In this way the scientific knowledge of nearly two hundred technical specialists could, if necessary, be brought to bear on a problem, with the understanding, of course, that no fellowship donor's interests are to be injured in any way by the release of confidential information. Then, too, the archives of the Institute are a vast storehouse of information on problems that have been investigated in the past. This intramural collaboration and recorded experience are closely controlled by the Institute's executive staff, in order to safeguard the interests of all parties concerned.

THE SIGNIFICANCE of the discovery by Wöhler in 1828 that organic compounds could be built up from inorganic materials was to some extent lost sight of by the synthetic chemists of the last half of the nineteenth century. The investigators of this period, inspired by the possibility of producing in myriad numbers complex substances not found in nature, feverishly launched researches that filled the reference books with polysyllabic names. Regiments of these compounds died a natural death. With the turn of the century, however, the spirit of research in chemistry changed, especially in the organic field. A new domain has been opened by the realization that the structures of complex molecules, although they may not have been explained in detail, at least offer encouragement for further work.

The progress in resin technology has been especially notable. Formerly, the chemist was usually discouraged when resinous substances were obtained as reaction products. He generally disposed of the unattractive material immediately, and turned his attention to other reactions that gave more promise of yielding beautiful crystals or sparkling liquids. The present-day attitude is antithetical; no product is too tarry or messy to preclude consideration of its application to important industrial needs.

It was characteristic of the vision of Robert Kennedy Duncan, founder of the industrial fellowship system of Mellor Institute, that one of the first problems accepted under his then new and untried plan for co-operation between science and industry lay in the field of resins and plastics. From 1910 until 1913, L. V. Redman was engaged at the University of Kansas, during the latter part of this time with two assistants, on an investigation of the combination of phenolic substances with hexamethylene tetramine. This work was completed at Kansas after the foundation of Mellon Institute in Pittsburgh; during a few years Duncan supervised problems being carried on in both places. The study by Redman and his assistants resulted in the commercial manufacture of "Redmanol."

At the same time the analogous product called "Bakelite" had been developed by L. H. Baekeland. Later these two processes were united, and Mellon Institute is now carrying on an investigation of interest to this strong union. And the synthetic resins have played an important part in all recent technological progress.

The success attending the investigations of Redman on phenolic resins led to the establishment of an industrial fellowship for the study of casein plastics. Work conducted in Europe had shown that casein would combine with formaldehyde to yield resins with commercially important properties. The study began early in 1920 and had been brought to a successful conclusion a year later.

The process worked out in the Institute by George H. Brother and W. E. Vawter was established on a commercial scale in Long Island City, N. Y. This plastic, called "Karolith," has not yet become so important commercially as some of the other compositions; in Europe, however, where the artificial resins are less numerous and varied, casein plastics are much employed, and careful observers feel that they will become increasingly useful.

SHORTLY after Mellon Institute had been organized along its present lines in Pittsburgh, an industrial fellowship was founded by the Prest-O-Lite Company to study acetylene. It must be remembered that acetylene lighting was an important industry at that time; electricity had not yet displaced it from the automobile. During the course of this work it was found that ethylene could be made cheaply by a new process, and the question of how to utilize this gas was an interesting economic problem.

The World War solved this difficulty temporarily in the preparation of mustard gas, but the end of the war rendered it a comparatively useless product. Yet it seemed probable that some commercial uses for compounds from ethylene might be found, and the Carbide & Carbon Chemicals Corporation was organized to carry out these ideas. The success of this endeavor is well known, and the utilization of these ethylene derivatives, the processes of manufacture of which have been developed at Mellon Institute, has spread throughout the chemical industries.

Ethylene glycol and the related diethylene glycol attained popularity rapidly, not as substitutes for glycerine but as a boon to technologists in need of substances resembling glycerine but with somewhat different properties. As components of anti-freeze solutions, as dye solvents, and as softening or moistening agents, they found important applications. Diethylene glycol has achieved importance as a lubricant for worsteds and woolens. The dinitrate of ethylene glycol soon came into wide use as an explosive. Ethylene chlorohydrin is employed as a starting point in the synthesis of many industrially important compounds and it may be used as an agent to force the sprouting of certain plants. Ethylene dichloride, besides having good solvent properties, has been found to be an excellent insecticide, and ethylene oxide is doing yeoman service as a fumigant. A whole group of related derivatives showing a gradation in properties has been immediately adopted as resin and lacquer solvents.

Triethanolamine, although a new compound in the commercial sense, possesses properties that promise tremendous possibilities. As an aid to the penetration in and adhesion or to porous material, as an emulsifying agent, and as an ingredient in cosmetics it has immediately found a demand, and unquestionably the number of uses will expand rapidly.

The most recent developments along these lines have been in the production of ethyl alcohol, ethyl ether, methanol, and vinyl compounds. The vinyl resins, in particular, are substances that will find many important uses. They are colorless, transparent, waterproof, and resistant materials that may be applied as protective coatings or may be molded into any shape.

The history of this rapid commercial

Mellon Institute of Industrial Research at Pittsburgh

development of organic compounds which but a few years ago were chemical rarities or unknown is one of the romances of chemistry. The wide uses that the materials have found have been in large measure due to work on the industrial fellowship in describing accurately the physical properties, such as the solubility relations, of these various compounds. This basically essential activity has indicated the procedures to follow in the subsequent merchandising research in the instance of each product.

THE BACKGROUND of the work that led to the use of acetylene as a starting point for the synthesis of organic compounds is somewhat similar to the history of the Carbide & Carbon Chemicals Corporation. Acetylene was available in quantity; research was necessary to point the way to successful commercial utilization. The growth of the Niacet Chemicals Corporation is a proof of the soundness of the investigational program.

Acetaldehyde and its derivatives prepared synthetically have become available in large quantities as a result of this work. Acetaldehyde has achieved importance because of its usefulness in synthesis and its solvent properties. It serves as an intermediate for the preparation of the substances mentioned below as well as of acetic acid, lactic acid, quinaldine, chloral, chloroform, acetyl chloride, acetic anhydride, and certain synthetic resins. Acetic acid is commercially the most important development of this work. Acetaldol, or "aldol," has valuable synthetic applications. Crotonaldehyde is a good solvent for many purposes and is used in many syntheses. Paraldehyde has found considerable use in the production of rubber accelerators and synthetic resins. It is also a good solvent for varnishes, fats, waxes, rosins, natural and synthetic resins, and vegetable oils.

A lesson in the patience that is sometimes necessary to reap the reward of research comes from the history of the industrial fellowship that "put cotton shirts on wieners." Ten years passed between the first experimental work and commercial production, but the faith of the fellowship donor, E. O. Freund, in the ultimate success of a carefully planned research program did not succumb to the early disappointments.

The steps in the progress of this investigation are in many respects typical of the paths of industrial research. First of all, a thorough bibliochrestic survey of the field of edible food containers was made. The possible raw materials were examined critically, and cellulose was finally chosen. It was then necessary to determine which process of using cellulose was most promising.

The viscose process was finally shown to be most adaptable to the work, and the study was then directed to the modification of this method to the production of seamless tubing. The method of preparing the cellulose solution, the aging, and the technique of making the film all required detailed study. The non-continuous pilot plant was the next step, and then the continuous semi-plant-scale manufacture. The solution of difficulties in adapting the finished product to actual use as a sausage casing required a long time.

Finally, in 1926, the process was under way in the factory of the Visking Corporation, in Chicago. The production, measured in length of seamless tubing, has now attained 200 miles per day. The cellulose casings are, of course, edible. The fact that they do not stick to the sausage, however, is made use of in preparing skinless frankfurters. Candies as well as meats are now being marketed in Visking casings.

WHEN the Koppers Company was organized, the Koppers byproduct oven developed in Germany was taken over. Much applied research and engineering ingenuity were required to adapt it to American conditions, and, in addition, many improvements in plant design, new uses for products, and betterment of the quality of coke were worked out. Prior to the entry of the United States into the World War, the Koppers Company conducted an energetic campaign for the installation of new byproduct coke ovens and benzol-recovery plants. It is probable that the greatest service of the Institute to national defense was rendered in research on the recovery of toluene from carburetted water gas. The solution of this problem was effected in a remarkably short time, and toluene was soon available at a rate of 1,000,000 gal. per year. When the special demand for this hydrocarbon ceased at the close of the war, the fellowship developed a new method of gas purification in which much of the toluene-recovery equipment is used. The same process is now in use for natural gas. Additional liquid purification procedures have been developed which permit the recovery of finely divided sulphur and other salable products.

An inexhaustible field for research exists in the byproducts of coke manufacture. As chemical industry progresses, the finished product of today will be the raw material of tomorrow, and in elaborating the manufacture of new commodities new byproducts are continually attracting the chemist's attention. Already we have, as a result of the fellowship's work, disinfectants, fungicides, insecticides, varnishes, paints, resins, resin intermediates, electrical insulating materials, turpentine substitutes, linseed-oil substitutes, wood preservatives, etc., and we may look forward with confidence to an ever-increasing number of such products.

The six preceding examples of new industries present some striking cases of the concrete value of research. The list of similar achievements at Mellon Institute in which a new branch has been added to an existing industry covers a wide field of chemical technology. The following illustrations have been chosen as representative of the scope and nature of the investigations.

The chrome-plating of aluminum was developed to commercial applicability and is now in actual use on a large scale. "Arkady" yeast food, butane gas for metal-cutting operations, a widely used dental cement, the mothproofing agent "Konate," and several insecticides, including "Fly-Tox," all were developed under the aegis of Mellon Institute. A fellowship has contributed important steps in the technology of organic rubber accelerators. The working out of a vanadium catalyst for the manufacture of sulphuric acid, and research contributing to improvements in various types of refractories and in the development of several new refractories are contributions to vital industries. Productive work in the hydrometallurgy of copper led to a process for the recovery of cuprous sulphide and to the use of a new series of flotation agents. Further achievements include new sanitary enamels, two new breakfast foods, a novel heat-insulating material, a series of vegetable adhesives, improved roofing materials, and better varnishes and lacquers.

Compressed Gases 1927-1929

New Bureau of Census figures on compressed and liquefied gases, shown below, demonstrate not only the rise of new industries but also the progress in production and lower prices among the older ones:

	1929	1927
Compressed and liquefied gases made in all industries, aggregate value	$68,224,085	$61,864,189
Made in the compressed and liquefied gas industry, value	51,108,308	50,067,106
Made as secondary products in other industries	17,115,777	11,797,083
Ammonia, anhydrous:		
Pounds	173,637,852	45,115,020
Value	$10,691,442	$4,011,362
Carbon dioxide:		
Pounds	88,186,356	74,344,287
Value	$6,280,647	$6,048,424
Chlorine:		
Pounds	241,295,383	180,163,438
Value	$5,629,102	$6,678,145
Hydrocarbon gases:		
Acetylene—		
M cubic feet	989,228	682,481
Value	$16,282,395	$16,196,388
Pintsch—		
M cubic feet	120,555	177,460
Value	$942,194	$1,408,211
Other, value	$1,096,983	$1,007,869
Hydrogen:		
M cubic feet	178,442	103,714
Value	$1,367,470	41,982
Oxygen:		
M cubic feet, total	3,044,317	2,359,896
Liquefaction process	2,842,015	2,086,301
Electrolytic process	202,302	273,595
Value	$23,231,701	$23,986,881
Nitrous oxide:		
Gallons (thousands)	116,479	66,392
Value	$1,296,392	$809,614
Sulphur dioxide:		
Pounds	11,958,846	11,003,719
Value	$703,177	$720,470
Other gases, value	$702,582	$254,843

Organic Synthetics in Battle Array

Contests of every type encountered, including inter-commodity, inter-process, inter-company, and international, with ramifications into a multitude of industries

An Editorial Staff Interpretation

COMPETITION among the organic materials produced by modern synthesis is a free-for-all battle, with "no holds barred." Every commodity seems aligned against every other one for each type of market. Blood brothers within any corporate family or within any particular scientific family have no hesitancy in striking each other down without warning, in order to appropriate new markets. Stability in utilization practice and "exclusive" markets are a thing almost unknown in the last few years in this field. The consequences of synthetic developments are far-reaching, permeating virtually all branches of industrial practice, both within and without the chemical industries. One is reminded of the cartoons of Rube Goldberg, for the discovery of a new catalyst oftentimes sets in motion a chain of events affecting raw materials, processes, products, and even corporate earnings of seemingly well established groups.

This competition reaches international proportions. The maker of ferroalloys at Niagara Falls may even be financially interested in the sugar crop of Java (we will tell you why a bit later). And international cartels and agreements, seeming monopolies with large profits, and the conventional flow of commodity in industrial channels all find themselves but a part of the great interlocking, interdependent industrial activity which has grown within a decade from academic laboratory findings to its present stature of world-important chemical engineering industry.

SOLVENTS were the first and most conspicuous commodities to enter the lists seeking the favor of the fair lady Profit. And this fickle dame has cast smiling glances at first one and then another of the synthetics. In fact, it appears that hardly are the hopes of one product aroused in any field of solvent application than along comes another more acceptable suitor which monopolizes attention through offering some new and hitherto unavailable favor.

Formerly the mere ability to dissolve a substance was regarded as a significant, in fact almost a determining, factor in the acceptability of a chemical as a solvent. Now this property, though not neglected, is usually overshadowed in importance by many other considerations. The solvent must not only dissolve the desired wax, lacquer, or other industrial material; it must release the dissolved substance at exactly the desired rate through a vapor-pressure curve of appropriate slope and shape according to the character of the application to which the dissolved substance is to be put. The user asks also as to the viscosity, the resistance to hydrolysis, the corrosive action, the solvent or destructive action on other substances, including containers and conveying materials. Indeed, the purchaser is so fussy as to set up a whole list of criteria which the solvent maker must now meet if he is successfully to retain a hold on his solvent market.

IN THE field of lacquers there are low boilers, medium boilers, and high boilers, defined so largely by the shape and position of their vapor-tension curves and rates of evaporation at the temperatures customary for lacquer application. Within each group one has to choose from the alcohol, the ketone, and the ester type of solvent, and more recently there have been added that group of synthetics which combine alcohol and ester or ketone and ester characteristics and favorable behavior. One of the earliest of these "combination-type" solvents was ethylene glycol monoethyl ether, marketed as cellosolve. But, recognizing the tendency of this lacquer solvent to produce a faint blush under unfavorable high-humidity conditions of exposure, its makers advanced to modified forms, including acetate derivatives and others, retaining as fully as possible the original advantages and eliminating the unwanted "bloom."

Furthermore, in many cases solvents for lacquer and similar uses are modified by mixture with cheaper diluents, such as toluene or alcohols, and various organic acetates. Through wise blending in this fashion the maximum of effectiveness, an approach to ideal performance with a minimum of cost, is being attained. The whole situation well illustrates, however, that no one of these commodities has anything like a dominating position in the lacquer field, nor is there likely to be any dominating chemical in this or in like applications, because of the wide variety of formulas that the ingenious makers of surfacing materials and large users of these commodities are constantly developing.

TOXICITY of vapors has long since been recognized as a handicap of benzol in industry. It has been less frequently recognized as a limitation in the use of carbon tetrachloride. But recently forward-looking producers of synthetic chemicals have squarely faced this sort of issue and are having thorough and impartial studies made of the physiological effect of their new products before they are extensively marketed in any way that may produce danger to employee personnel of user companies. Such studies have disclosed, for example, that ethylene dichloride and trichlorethane, much more resistant to hydrolysis than carbon tetrachloride, may often be very successfully substituted either wholly or in part for the older compound. The incidental advantages of freedom from corrosion due to hydrochloric acid formed by hydrolysis has been an added incentive to users to make this substitution, since the newer synthetics are virtually wholly resistant to such decomposition under all ordinary conditions of use in the presence of water or steam. In a few cases the slightly preferable odor of the dichloride offers an additional advantage.

This matter of toxicity, and possible public exposure to chemical hazards, has reached its climax in the bitter controversy as to the merits of ethyl alcohol and methyl alcohol for antifreeze applications. In recent issues of *Chem. & Met.* there have already been given summaries of the preliminary gov-

ernment report on proper conditions for use of methanol and some of the other important factors involved. That controversy is important here largely because it represents an instance in which all weapons of commodity competition appear to have entered. Some of the attacks remind one strikingly of the bitterness of overzealous partisan politicians in the heat of pre-election battles. There has undoubtedly not been another example of equally bitter or equally far-reaching controversy in the field of commodity competition among chemicals for a long time past. More will be said later as to the use of these and other synthetics in the anti-freeze field.

Disinfectants, fungicides, insecticides, and similar pest controls are now legion. The day of the iodine bottle as a dominant factor in the household medicine cabinet was first seriously questioned with the production of a number of antiseptics which found favor during the World War.

Now there are a dozen substances made, not all strictly within the field of organic synthetics, that offer themselves with arguments of real merit for this very extensive field of household antiseptics and sanitary agents. Among the recent additions worthy of note are hexylresorcinol, orthophenylphenol, and a number of other closely related compounds that were either unknown or mere laboratory curiosities a few years back.

The value of these new compounds extends far beyond household purposes. Germicidal applications as dips, sprays, or fumigants are increasingly widespread. Glue preservation, preventing mold development, insecticidal use for control of chicken lice and sheep ticks, are among the less spectacular, but none the less important, applications. Some backers of orthophenylphenol regard this synthetic as not only the newest but also the most promising of all industrial antiseptics applicable in the dairy industry. It is apparently 30 or 40 times as toxic against typhus and other types of contaminating bacilli as is phenol, yet it is non-toxic to human beings and may safely be used on the cattle, about the dairy barn, and elsewhere through milk handling systems. Its most ardent advocates give the impression that the dairy industry is about to become as aseptic as the best managed surgical operating room in a modern hospital.

APPLICATIONS for germicidal or fungicidal purposes are not limited to the animal industries. An appropriate treatment of seed grains is now widely recommended by agricultural experts for control of molds. And even the speed of germination of seeds or the reactivation of dormant buds can be largely affected by skillful treatment with properly selected synthetic materials. One such application of very large industrial significance to the florist is the ability to cause early development of dormant buds in order to secure sprouting and blooming according to schedule; in anticipation of Easter, for example. Whether these synthetics will go so far as to enable one to change the time of bloom and fruit at will is, as yet, doubtful; but apparently the plant physiologists, aided and abetted by the synthetic chemical makers, are busy at work and are producing what a few years ago were thought to be impossible things. In all of these fields the present applications are merely suggestive of the competition that is sure to follow as the potentiality of making a chemical synthetically to give almost any desired and almost any prescribed properties.

SOPHOMORE chemistry, including elementary organic, customarily produces many marvelous structural formulas and the most amazing variety of new reactions found on paper, but never experienced in the laboratory. Yet today, on an industrial scale, even some of the queer and apparently unworkable reactions that are no more strange than the sophomore examination paper are actually working. Not long ago it would hardly have been an acceptable answer to say that hydrogen is manufactured from carbon monoxide. Yet today that is a strictly correct technical statement, assuming one is willing to allow the proponent access to an adequate water supply. This is but one of the new types of reactions made possible by the development of industrial catalysts of highly selective performance.

Twenty years ago when one spoke of a catalyst the first thought was of platinum or palladium. Today those precious metals, while still largely used by the chemical engineer in this connection, compete with newer types of catalysts that have become more common industrially. The making of hydrogen by reaction between carbon monoxide and steam is but one of the successful developments of this nature which lie at the root of a whole new type of organic synthesis. Among the first products of such reactions is methanol. Indeed, today the making of synthetic methanol by direct combination of hydrogen and carbon monoxide has progressed so far that the synthetic product dominates the industrial situation of the world and there appears to be no hope for resuscitating "wood alcohol." Apparently the makers of that commodity through wood distillation long overslept their economic alarm clock, and they have lost substantially all of their opportunity to do business with the industry of today.

It is well known that like reactions, combining hydrogen, water vapor, carbon monoxide, carbon dioxide, in almost any desired proportion can be accomplished for the production of a wide variety of other synthetics. We do not yet have fully developed and commercially applied selective catalysts thoroughly satisfactory for all of these processes. There is every reason to believe, however, that several such developments are now in the making and that the new processes of the direct combination type will make it very difficult for indirect synthesis to remain successful for long, unless the raw material be very cheap and the process highly efficient.

Much of this type of development is a direct outgrowth of the fundamental work done on high-pressure technology and catalytic-reaction control in the field of direct synthesis of ammonia. Apparently it is not at all unlikely that natural and indirect sources of manufacture, which are now experiencing such vigorous competition from synthetic ammonia, will suffer a like attack and in like manner pass from dominating position in the case of many other commodities.

This comparison between synthetic methanol and synthetic ammonia leads to one interesting observation as to cost. It is probably safe to say that the cost of raw materials, the cost of the catalysts, and the capital charges on equipment required are not very different in the case of methanol made synthetically from those in the case of ammonia similarly produced. It has already been demonstrated with complete industrial convincingness that synthetic ammonia can be manufactured in a well-managed and efficient large-scale plant for a factory cost something like 3 cents per pound, not including selling expense and profits. Suppose that methanol could be made and marketed on an analogous basis. Obviously, then, this chemical would enter the competitive situation on a factory cost basis of from 20 to 25 cents per gallon. Like arithmetic procedure gives equally startling suggestion regarding the prospective cost of some other chemicals that may well appear on the market as a result of commercialization of direct addition procedures.

ONE should not limit such philosophizing to the simple group of alcohols; it would be equally applicable in several other unrelated chemical groups, including acids, ketones, and aldehydes if markets comparable in size to ammonia and methanol could be developed. Technically this development apparently hinges on securing sufficiently selective action of the catalysts so that the products made will not be unduly expensive of purification because of the presence of too wide a variety of compounds in the crude synthetic product. Methanol thus far is the only important product meeting this requirement.

The availability of cheap and pure ethylene, propylene, butylene, and other unsaturated hydrocarbons has made possible a large production of higher alcohols at comparatively low cost. These include normal, iso- and secondary propyl, butyl, amyl, and hexyl alcohols which afford in turn a still wider variety of esters. To a limited extent the lower alcohols of the series are competitive with ethyl alcohol as solvents, but principally they enter, to-

gether with their esters, the battle for use in lacquers, plastics, and other industrial products.

PROCESS COMPETITION is perhaps best illustrated in the field of ethyl alcohol. There remains today as still dominant in that field the fermentation processes. But when one refers to fermentation he no longer can limit his consideration to molasses and corn. The advance in price of corn during the past year very promptly led the largest manufacturer of fermentation products using that raw material to announce that its processes were readily adaptable to rye, and that this cheaper grain would be used extensively if the price of corn advanced unduly. In Europe the use of a variety of agricultural raw materials, particularly potatoes in Germany, is officially encouraged through the requirement that motor fuel must include a certain percentage of alcohol. Apparently that is the Continental method of solving farm relief, at least on a small scale.

In the United States, molasses remains the major raw material. But the price of molasses is far from a fixed thing. Wide, uncontrolled, and almost unpredictable swings in molasses price have occasioned much of the financial difficulty of the fermentation industry making industrial alcohol in the United States during recent years. At 4 or 5 cents per gallon of molasses delivered at the Eastern or Gulf seaboard ports this industry can probably make alcohol for just about the figure suggested in an earlier paragraph as the probable cost of methanol if it could safely be compared with ammonia. Hence, since these two closely related alcohols are today highly competitive, it seems important that molasses be maintained at this low figure or the fermentation division of the alcohol business is going to suffer from synthetic competition much as the wood distillation business has suffered. And there is grave doubt whether the sugar producer is going to be willing to co-operate to the end of maintaining his molasses markets against synthetic-process competition by accepting so low a price as this for the bulk of his output. If he does not accept it, then we may have still further commodity adjustments to make in the sugar industry itself.

IT IS at this point that one can quickly see the connection previously suggested between ferro-alloys at Niagara Falls and the Java sugar business. Obviously, the maker of methanol using furnace gases from the alloy furnaces wants to know the attitude, prospective crop, and particularly the molasses output of the world. He is interested not only in Cuba, from which our United States molasses supply comes, but also in such remote supplies as that of Java, since increasingly there must be a world level of molasses price. Even long sea hauls are not sufficient to buffer out the influence of bumper or slack sugar crops in remote parts of the world on synthetic production of competing chemicals within the United States. Undoubtedly, therefore, many of the chemical industries that have no desire to enter the sugar business were quite anxious to find out what was going to develop in the international conversations which were lately so nearly successful in securing a world control on the sugar export from the principal producing countries. Industry is, indeed, intimately interlocked.

Ethyl alcohol made from ethylene by synthetic procedures is now an accomplished fact, furnishing a significant percentage of the United States supply. Thus far, this development has not produced any flood of cheap alcohol with far-reaching consequences like the contemporary development of synthetic methanol. Obviously any such parallel action cannot quickly result, because of the restraining influence of alcohol control by the U. S. government, both for tax and for prohibition purposes. However, it appears that at least 7 or 8 per cent of the United States production of alcohol in 1930 came from synthetic plants.

WITHIN a few years we may expect a very much larger percentage from such sources if industrial development results in the expected lowering of costs. The consequences undoubtedly will be the maintenance of a much lower price level and the encouragement of the use of alcohol as a solvent on a larger scale and its application in many non-solvent lines that are not altogether feasible at former prices. Fuel use in competition with gasoline, however, is not likely for a long time to come. Fortunately, the federal departments look with sympathetic and understanding interest on new processes for ethyl alcohol making and are willing to allow them to develop as rapidly as their economic merit deserves, according them privileges of manufacture and sale, of course within the restrictions necessary for legal control under the present laws as to taxes, denaturing, and so on.

The denaturing of alcohol to permit

Table I—Synthetic Organic Chemicals of Non-Coal-Tar Origin: Imports and Production 1927-1929

(Data From U. S. Tariff Commission)

	1927			1928			1929		
	Imports[1]		Production[2]	Imports[1]		Production[2]	Imports[1]		Production[2]
	Quantity, Pounds	Value	Pounds	Quantity, Pounds	Value	Pounds	Quantity, Pounds	Value	Pounds
Acetaldehyde	50	$20	.....	4,472	$803	[3]	10,770	$1,622	[3]
Paracetaldehyde	21,258	4,017	.....	19,587	3,216	[3]	40,853	7,319	[3]
Formaldehyde, solution	1,347	89	29,920,072	4,188	194	38,717,732	.....	.....	51,786,422
Hexamethylenetetramine	3,417	1,715	1,315,213	5,898	1,643	1,661,645	5,562	1,857	2,368,020
Acetic or pyroligneous acid, containing by weight—									
Not more than 65 per cent acetic acid	6,766,512	350,421	.....	12,163,499	644,816	[3]	21,410,253	1,289,002	[3]
More than 65 per cent acetic acid	3,784,504	454,382	.....	6,058,077	728,739	[3]	7,824,521	727,847	[3]
Formic acid	3,214,642	230,565	.....	2,250,090	174,246	[3]	1,386,608	108,797	[3]
Gallic acid	.....	.....	515,876	.....	.....	432,571	.....	.....	458,389
Lactic acid, containing by weight 55 per cent or more of lactic acid	202,352	63,650	.....	282,598	88,438	[3]	322,110	89,115	[3]
Oxalic acid	1,843,732	98,657	.....	[4]890,203	[4]46,447	[3]	1,346,053	71,193	[3]
Pyrogallic acid	.....	.....	.....	.....	.....	142,335	12	33	134,994
Butyl alcohol	31,751	5,569	[5]48,922,561	[6]39,903	[6]7,957	[5]49,860,798	[6]935	1,127	[7]67,500,000
Methanol	[8]1,714,442	718,412	.....	[9]379,291	129,339	[8]	[8]53,327	214,667	[8]
Carbon tetrachloride	.....	.....	16,550,026	.....	.....	19,764,908	20	7	34,719,934
Chloroform	11	42	.....	51	72	[3]	30	35	2,767,301
Diethylbarbituric acid	.....	.....	.....	.....	.....	.....	30,874	[10]248,986	[3]
Glycerophosphoric acid, and salts and compounds	50,279	56,205	.....	28,550	43,726	[3]	25,779	46,532	[3]
Ethers and esters, containing not more than 10 per cent alcohol—									
Ethyl ether USP	22	12	5,855,462	.....	.....	5,933,297	2,262	320	6,147,393
Butyl acetate	.....	.....	26,304,243	5,347,902	701,827	30,029,505	7,824,234	981,953	38,780,656
Amyl acetate	300	150	2,421,301	539	211	4,290,117	300	82	5,832,145
Ethyl acetate	3,748	391	49,203,156	.....	.....	58,578,026	74	73	73,895,640
Other, n. s. p. f.	[11]5,789,042	846,334	.....	678,911	113,935	.....	85,314	33,673	.....
Tetrachloroethane	72,977	3,735	.....	46,862	2,544	[3]	99,708	4,387	[3]
Trichloroethylene	2,567	184	.....	154,358	9,382	[3]	223,653	11,183	.....
Thymol	18,420	40,269	.....	17,636	29,928	.....	22,541	36,935	.....
Urea	814,309	51,880	.....	1,788,927	101,900	.....	4,558,583	228,401	.....
Vanillin[13]	[12]3,178	20,961	301,251	18,759	129,917	281,694	.....	.....	.....

[1]Foreign Commerce and Navigation of the United States.
[2]Census of Dyes and Other Synthetic Organic Chemicals.
[3]Not publishable.
[4]T. D. 40604.
[5]*Wall Street Journal*, Apr. 8, 1929.
[6]T. D. 37577.
[7]Production of Commercial Solvents Corporation; *Wall Street Journal*, June 13, 1930.
[8]Gallons.
[9]Gallons, T. D. 41892.
[10]Based on the American selling price.
[11]Includes butyl acetate, imports of which in the last 9 months of 1927 were 4,958,560 pounds, valued at $679,499.
[12]Data from invoices indicate a total of 3,795 pounds.
[13]Vanillin, listed prior to 1929 in the non-coal-tar group, is included in 1929 in the coal-tar products. For imports in 1929, see p. 62; for production see p. 74

both unrestricted general use of completely denatured material and the preparation of specially denatured goods under special formulas has occasioned a great deal of extensive research. Strangely enough, in this field of denaturant making the synthetic products apparently have lost out to other commodities. Even though methanol in the form of genuine wood alcohol was recognized as a denaturant, substitution of synthetic methanol was not permitted. This latter product, by its very purity, freedom from noticeable odor, and taste characteristic of the wood product, did not carry with it its own flag of warning. Hence, the federal authorities have never accepted synthetic methanol as a satisfactory denaturant. Now even wood alcohol has been eliminated from this use, presumably in order that denatured alcohol may cease to be the occasion of fatalities caused by diversion. Beginning with the first of 1931 it was required that a mixture of aldehol and alcotate, special odorous petroleum products, be used for completely denatured Formula No. 5, instead of a mixture of wood alcohol and aldehol, as formerly. And the combining under Formula No. 1 with still larger percentages of wood alcohol has been abandoned altogether as of the same date. Thus not only the synthetic but also the natural methanol is eliminated from what has been one of the largest applications of this chemical. The noxious odor and foul taste are intended to make the completely denatured goods self-warning to those who might be tempted to divert them from legitimate channels. Thus an incidental byproduct of the petroleum industry enters in a competitive way and completely supplants methanol.

Table II—Production of Organic Chemicals Reported by the Census of Manufactures, 1927-1929

	1929	1927
Alcohols:		
Amyl alcohol, including fusel oil—		
Total production, gallons	390,963	182,054
Made and consumed in the same establishments, gallons	49,556	6,985
For sale—Gallons	341,407	175,069
Value	$405,916	$277,069
Other (butyl, propyl, synthetic methanol, etc.), not including glycerol (see "Glycerin"), value	$11,389,851	$9,667,376
Amyl acetate:		
Total production, gallons	262,825	316,578
Made and consumed in the same establishments, gallons	81,631	97,702
For sale—Gallons	181,194	218,876
Value	$316,687	$435,656
Butyl acetate:		
Total production, gallons	6,006,081	4,220,490
Made and consumed in the same establishments, gallons	1,618,313	1,878,479
For sale—Gallons	4,387,768	2,342,011
Value	$5,631,741	$3,613,182
Carbon bisulphide:		
Pounds	71,009,798	44,972,489
Value	$2,859,584	$2,159,524
Carbon tetrachloride:		
Pounds	32,712,749	17,026,466
Value	$1,728,034	$1,036,165
Chloroform:		
Pounds	3,081,920	2,972,889
Value	$595,759	$604,317
Ether:		
Total production, pounds	6,936,047	8,068,052
Made and consumed in the same establishments, pounds	472,494	1,933,281
For sale—Pounds	6,463,553	6,134,771
Value	$1,897,194	$1,720,374
Ethyl acetate:		
Total production, gallons	11,065,326	6,638,147
Made and consumed in the same establishments, gallons	488,941	2,031,245
For sale—Gallons	10,576,385	4,606,902
Value	$8,709,387	$3,701,084
Ethyl nitrite:		
Pounds	38,321	39,462
Value	$26,589	$29,454
Glycerin:		
Crude[2]—		
Pounds	28,661,730	26,999,863
Value	$2,347,748	$3,942,991
Refined[2]—		
Pounds	113,030,511	89,584,918
Value	$12,704,409	$19,184,806
Methyl acetone:		
Pounds	4,675,140	2,603,520
Value	$574,736	$352,947
Plastics:		
Pyroxylin—		
Total production, pounds	25,283,235[3]	19,503,710
Made and consumed in the same establishments, pounds	4,856,625[3]	3,205,687
For sale in form for further manufacture—Pounds	20,426,610[3]	16,298,023
Value	$18,063,154[3]	$14,409,668
Finished articles of pyroxylin made in the producing establishments, value	$10,530,214	$6,801,355
Other plastics (phenolic resins, rubber substitutes, casein plastics, etc.), value	$8,322,520	$6,991,842
Vanillin:		
Pounds	317,355	299,624
Value	$1,858,228	$1,922,510

*Organic.

[1]Not including ethyl alcohol, nor methanol made from the distillation of wood. For statistics on methanol other than synthetic), see report on "Wood distillation and charcoal manufacture."

[2]Production for sale by chemical and soap-manufacturing establishments only. Total production of crude glycerin, 80 per cent basis (Quarterly Census of Animal and Vegetable Fats and Oils): 1929, 140,179,568 pounds; 1927, 128,208,642 pounds.

[3]Revised; originally published, under date of September 11, 1930, as follows: Total production, 26,820,171 pounds; made and consumed, 4,137,709 pounds; for sale in form for further manufacture, 22,682,462 pounds, valued at $19,754,391.

The consequences of eliminating methanol as a denaturant, the development of synthetic methanol, and the increase in potential supplies of ethyl alcohol all have centered competition of these two oldest and best known organics in the anti-freeze market. For the first time the winter of 1930-31 sees the extensive use of methanol for prevention of freezing in automobile cooling systems. There is, therefore, in this application now an intensive competition among methyl alcohol, ethyl alcohol, glycerine, and ethylene glycol. This competition is of peculiar intensity and bitterness, due to the controversy over the possible hazard in widespread use of methanol in the hands of the layman. The real competition, however, is rooted in the technical characteristics as well as in the price structure of the four anti-freeze chemicals. This competition is, indeed, one of the most interesting and is suggestive of many of the factors which much more highly technical applications of chemicals often experience. It therefore deserves much more comprehensive study on the part of industrial chemists and chemical engineers than it apparently has had.

ANTI-FREEZE application of chemicals demands consideration of quite a variety of properties. In the first place, the lowering of the freezing point of the water with which the chemical is mixed must be adequate. It is not generally appreciated that pound for pound in a mixture methanol produces the lowest freezing point of any of the four, with ethylene glycol a close second, and ethyl alcohol and glycerine about tied as a rather poor third and fourth. It is still less widely understood that for a given degree of protection against freezing the vapor loss of methanol-water mixtures is lower than of ethyl alcohol-water mixtures giving like protection. Hence evaporation of methanol from the radiator is less rapid than of ethanol if mixtures are used giving like protection; this despite the lower boiling point of the methanol when water-free.

The advantages of a non-evaporating anti-freeze compound have been so widely advocated by proponents of glycol and glycerine that they do not require emphasis. It has been as widely advertised that these two chemicals are also safer for use if the careless filling-station attendant is likely to spill them on the lacquer-finished car; and there is less danger of vapors from overheated radiators causing damage by mottling the lacquered surfaces with them than with either of the alcohols.

Starting an automobile on a cold winter morning is troublesome enough at the best. Apparently under such unfavorable conditions the glycol mixture giving adequate anti-freeze protection has a much greater fluidity than a glycerine-water mixture of like anti-freeze value. These and a dozen other

characteristics, desirable and undesirable for anti-freeze solutions, have been thoroughly studied by the Bureau of Standards. That bureau has pointed out the very great disadvantage of anything like salt or calcium chloride, which was used in early days by some thoughtless motor makers and service stations. And none of the other suggested materials that have been tested approaches in satisfaction, according to the result summarized by the Bureau, any one of these four organic solvents.

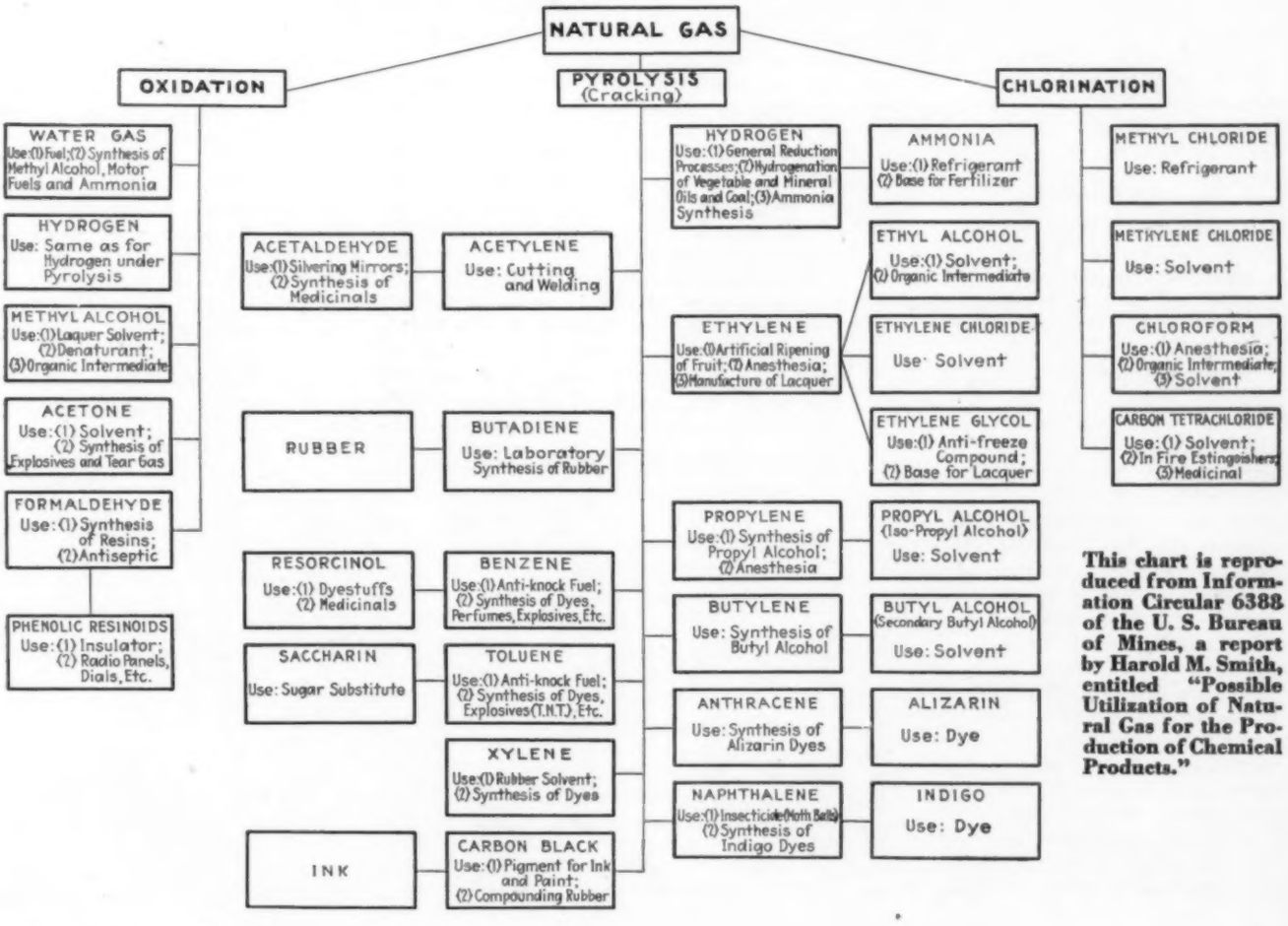
It is too early to say just how this battle among the four anti-freeze compounds will progress. It is safe to say, however, that even the highest priced of the four, glycol, stands a good chance for maintaining itself in competition because of its permanence throughout a season and some of its other favorable characteristics. Doubtless the competitive battle will continue for many seasons to come, perhaps affected more than anything else by changes in price relationship which undoubtedly will result from the enlargement and the increased efficiency of synthetic plants.

RAW MATERIALS of unlimited supply are an essential prerequisite of most synthetic processes. Glycerine, formerly of comparatively limited supply as a byproduct, was in that respect at some disadvantage as compared with its nearest relative, glycol, in the anti-freeze field; but synthesis of glycerine is now feasible and only cost relations determine the competition. To some extent limited supplies of molasses are bound to operate in like fashion to restrict the maximum potential development of one division of the fermentation industry. It is impracticable to increase molasses supply by any large percentage, and probably it will remain so, even though the sugar man might find that a pound of sucrose in molasses was worth as much to him as a pound of sucrose in raw sugar. (This last possibility is not seriously suggested as a probability.) No like restraint is found on that division of the fermentation industry which uses corn, rye, or potatoes as raw material. Such raw materials may have a season or two of short supply or of unduly high price, but over a period of years there is no doubt that agriculture will take care of the supply in so far as the alcohol maker may call for such raw material. And by adapting the process to corn or rye and to potatoes and other starch, the maker of alcohol could presumably protect himself in a season of shortage. And yet, when all is said and done, it is unlikely that any of these raw materials will compete with coal, petroleum, and natural gas as a source of carbon and with water as a source of hydrogen.

On occasion the availability of a byproduct furnishes in some unrelated industry a new raw material of highly competitive form. One example of this recently encountered by organics was in the making of methanol and formaldehyde from natural gas. This production was merely an incidental consequence of the gas man's desire to lower the oxygen content of his gas, to prevent internal corrosion of pipe lines. The effect on the chemical market was just the same, regardless of the strange motive that may have inspired its manufacture.

One might proceed indefinitely in the multiplication of examples of competition among synthetics. The number of cases and of types of competition seems unlimited; to cite all is impossible. It is evident from the comparatively few cases described that within this field of competition there is needed the best of research skill, the most aggressive merchandising, and managements alert to grasp every commercial and technical advantage which presents itself. Likewise, management must be prepared to avoid the pitfalls of commercial error and to meet intensive commodity competition from many sources.

Natural Gas as a Possible Source of Synthetic Organic Chemicals


NATURAL GAS
OXIDATION
PYROLYSIS (Cracking)
CHLORINATION
WATER GAS
Use: (1) Fuel; (2) Synthesis of Methyl Alcohol, Motor Fuels and Ammonia
HYDROGEN
Use: Same as for Hydrogen under Pyrolysis
METHYL ALCOHOL
Use: (1) Laquer Solvent; (2) Denaturant; (3) Organic Intermediate
ACETONE
Use: (1) Solvent; (2) Synthesis of Explosives and Tear Gas
FORMALDEHYDE
Use: (1) Synthesis of Resins; (2) Antiseptic
PHENOLIC RESINOIDS
Use: (1) Insulator; (2) Radio Panels, Dials, Etc.
ACETALDEHYDE
Use: (1) Silvering Mirrors; (2) Synthesis of Medicinals
ACETYLENE
Use: Cutting and Welding
RUBBER
BUTADIENE
Use: Laboratory Synthesis of Rubber
RESORCINOL
Use: (1) Dyestuffs (2) Medicinals
BENZENE
Use: (1) Anti-knock Fuel; (2) Synthesis of Dyes, Perfumes, Explosives, Etc.
SACCHARIN
Use: Sugar Substitute
TOLUENE
Use: (1) Anti-knock Fuel; (2) Synthesis of Dyes, Explosives (T.N.T.), Etc.
XYLENE
Use: (1) Rubber Solvent; (2) Synthesis of Dyes
INK
CARBON BLACK
Use: (1) Pigment for Ink and Paint; (2) Compounding Rubber
HYDROGEN
Use: (1) General Reduction Processes; (2) Hydrogenation of Vegetable and Mineral Oils and Coal; (3) Ammonia Synthesis
ETHYLENE
Use: (1) Artificial Ripening of Fruit; (2) Anesthesia; (3) Manufacture of Lacquer
PROPYLENE
Use: (1) Synthesis of Propyl Alcohol; (2) Anesthesia
BUTYLENE
Use: Synthesis of Butyl Alcohol
ANTHRACENE
Use: Synthesis of Alizarin Dyes
NAPHTHALENE
Use: (1) Insecticide (Moth Balls) (2) Synthesis of Indigo Dyes
AMMONIA
Use: (1) Refrigerant (2) Base for Fertilizer
ETHYL ALCOHOL
Use: (1) Solvent; (2) Organic Intermediate
ETHYLENE CHLORIDE
Use: Solvent
ETHYLENE GLYCOL
Use: (1) Anti-freeze Compound; (2) Base for Lacquer
PROPYL ALCOHOL (Iso-Propyl Alcohol)
Use: Solvent
BUTYL ALCOHOL (Secondary Butyl Alcohol)
Use: Solvent
ALIZARIN
Use: Dye
INDIGO
Use: Dye
METHYL CHLORIDE
Use: Refrigerant
METHYLENE CHLORIDE
Use: Solvent
CHLOROFORM
Use: (1) Anesthesia; (2) Organic Intermediate; (3) Solvent
CARBON TETRACHLORIDE
Use: (1) Solvent; (2) In Fire Extinguishers; (3) Medicinal

This chart is reproduced from Information Circular 6388 of the U. S. Bureau of Mines, a report by Harold M. Smith, entitled "Possible Utilization of Natural Gas for the Production of Chemical Products."

Present Trends and Future Prospects In Fertilizer Manufacture

By C. L. Burdick
Assistant Chemical Director
Du Pont Ammonia Corporation
Wilmington, Del.

DURING the first two decades of the 20th century the American fertilizer industry grew to be a major business enterprise. The United States became the largest manufacturer of superphosphate, and in fact supplied almost the whole world with raw phosphatic materials. Phosphorus developed as the basic constituent of all fertilizers, and nitrogen and potash were regarded as the incidental additions to be included only in meeting minimum crop necessities.

Simultaneously this period witnessed the initiation of the large growth of the byproduct coke industry and the manufacture of byproduct ammonium sulphate. It had early been appreciated that this material was a desirable nitrogen carrier for crop growth. Its entrance in a large way into the fertilizer trade represented practically the first evidence of inter-commodity competition in the field. Almost at once there arose competition between byproduct ammonium sulphate and Chilean nitrate of soda, and price schedules for each were made with careful consideration always of the other commodity. The prices per pound of nitrogen in these two compounds remained on a close parity. There was, however, no inter-commodity competition in the phosphorus or potash branches of the industry until after the war period 1914-1918.

Rapid development of the synthetic nitrogen industry in Germany during the war years, and subsequently, was the widely-heralded event that inaugurated the present phase of inter-commodity competition among nitrogen products. Simultaneously, and without display, the American potash industry began to develop at Searles Lake and to demonstrate that it could stand alone against the Kali Syndikat monopoly. On the other hand, with the development of the Morocco and Oceanica phosphate deposits, the trade monopoly of the United States in phosphate rock had disappeared. At the present time every essential plant food element represents some phase of inter-commodity competition, international in scope.

It is the purpose of this article to describe some of the interrelated features and factors in the fertilizer industry, so that the reader may himself judge of the trends that are indicated. From the American point of view, it is believed these trends can be grouped with the consideration of the following questions:

1. What is the immediate situation, and what are the indicated future trends as respects the major plant foods, nitrogen, phosphorus and potash?
2. What is the indicated future of the "mixed fertilizer" industry?

Nitrogen-Containing Materials

According to the data of the National Fertilizer Association the present consumption of nitrogenous fertilizer materials is approximately as shown in Table I for 1929. In addition, approximately 120,000 short tons of nitrogen in various forms was used in the chemical and manufacturing industries during the year, 1929, this total comprising largely anhydrous ammonia (used as such or oxidized to nitric acid), sodium nitrate and cyanides. The total consumption of nitrogen in the United States in 1929 was, therefore, around 503,000 short tons. Simultaneously, in the neighborhood of 40,000 short tons of nitrogen, largely as ammonium sulphate, was exported.

To evaluate future trends in the nitrogen industry we should fix in mind the domestic production situation that will exist shortly with the completion of the extensions to synthetic ammonia plants now under way in the United States. These will be ready for full operation by the year 1932. Approximate total production capacity with present construction completed is shown in Table II.

Table I—United States Consumption of Nitrogenous Fertilizer Materials

	1929 Consumption, Short Tons of Nitrogen
From Chemical Sources	
Byproduct ammonium sulphate	150,000
Nitrate of soda (synthetic and natural)	110,000
Ammonia used as such	25,000
Cyanamide	30,000
Calcium nitrate	5,500
Ammonium sulphate-nitrate	4,500
Other carriers	2,000
	327,000
From Natural Organic Sources	
Cottonseed meal	11,400
Animal byproducts	7,800
Fish scrap and guano	8,300
Rough ammoniates, process tankage, etc.	13,500
Garbage tankage and sewage sludge	5,800
Miscellaneous	8,800
	55,600
Total from both sources	382,600

Assuming that the industrial demand for nitrogen products increases at the average rate of 7½ per cent, which has prevailed quite closely for the entire industry over the last 30 years, the chemical and industrial demand in 1932 may require as much as 140,000 short tons of nitrogen. Assuming also a continuance of the normal export business of 40,000 tons, this makes a total industrial demand plus export of, say, 180,000 tons of nitrogen. Simultaneously, the demand for nitrogen for agricultural purposes, if it continues its present trend, may be expected to reach 440,000 tons. This leaves a deficiency in domestic production of only 85,000 tons of nitrogen to be supplied by imports. If the nitrogen export business in ammonium sulphate should be lost because of the extreme competitive situation that prevails in outside world markets, the shortage in domestic production would be reduced to about 45,000 tons of nitrogen. This compares with average figures of approximately 210,000 tons of nitrogen in imported products hitherto consumed in our domestic market. The distribution of this nitrogen among the imported products has been approximately as given in Table III.

Essentially the outstanding items in the present domestic nitrogen situation are these:

1. During the year, 1931, the United States will become nearly self-sustaining as respects a balance between nitrogen production and consumption. There is thus reason to believe that imports of nitrogen products into the United States will drop sharply.
2. If imports of nitrogen products should be maintained even to a limited extent, then certain domestic products must lose correspondingly. It is reasonable to believe that this will mean the elimination of products of relatively high cost. The price level for natural organic nitrogen products is two or three times the corresponding price for inorganic nitrogen, and on this basis a large reduction in consumption of natural organic nitrogen products is one of

the first things to be expected. This is corroborated by the trend of consumption for these products, as disclosed by statistics over the last several years.

3. Further, it is well known that by relatively small additional investments, the capacity of the major American synthetic plants can be rounded out to figures easily 10 to 20 per cent above their present conservative ratings.

It is obvious from the above that, within a year, the United States will be practically self-sufficient as respects an over-all balance in prospective domestic nitrogen markets. We shall have enough total domestic nitrogen supply available to meet the country's demand. The problem is to apportion this nitrogen into forms to fit the demonstrated needs of agriculture. What are the probable forms in which this nitrogen will be marketed?

Trend Toward Synthetic Carriers

In general, because of cheapness, the trend is obviously going to be away from natural organic nitrogen carriers and toward chemical compounds of nitrogen. Cyanamide and urea are often classified as low-priced substitutes for natural organic nitrogen. For uses where inorganic residues in the soil are not permissible, or where by other tests cyanamide has not been found suitable, then urea is the only compound of this classification that is available. It is interesting to note that, on a nitrogen basis, urea now sells only slightly above ammonium sulphate and well below other high-priced nitrogen carriers such as sodium nitrate. Under these circumstances, it is natural that import statistics should show it to be the most rapidly increasing of any of the newer synthetic nitrogen products.

Table II—Approximate United States Production Capacity of Nitrogen Products

From Chemical Sources	Annual Productive Capacity, Short Tons of Nitrogen
Byproduct sulphate and byproduct ammonia plants as at present	180,000
Synthetic ammonia plants with present construction completed	300,000
From Natural Organic Sources	
Sources* as in Table I	55,000
Total prospective domestic production†	535,000 tons

*Presumed to be constant at present.

†This does not include sources of nitrogen on the Canadian side of the American border, such as the cyanamide plants at Niagara Falls and the synthetic ammonia plant now being built at Trail, B. C. From many points of view these should be classed in the domestic category, but in this article the nitrogen coming from these sources is treated as "imported."

As now incorporated in mixed fertilizer, anhydrous ammonia is the cheapest form of fixed nitrogen on the market; and it has also the same qualification as urea of not imparting any additional inorganic residue to the fertilizer or to the soil; and furthermore, its specific "conditioning" effect in mixed fertilizer, a purpose for which organic materials are often used, indicates that anhydrous ammonia practically falls within this same category. However, no synthetic product has been developed to date which will approximate the slow availability (sometimes advantageous) of the nitrogen from natural organic products.

Among the inorganic nitrogen carriers, byproduct ammonium sulphate will, in the writer's opinion, hold its premier position as the largest-tonnage nitrogen carrier for agriculture. It will be sold at price levels that unquestionably will make it the determinative factor in setting American nitrogen prices. This year it has touched a new low price for all time, present quotations being around $35 per ton or $1.70 per unit of nitrogen. This is in contrast to anhydrous ammonia at $120 per ton delivered, or $1.46 per unit of nitrogen; and sodium nitrate at, say $39 per ton or $2.50 per unit of nitrogen, ex-vessel, Atlantic ports.

Synthetic sodium nitrate is an important factor in the domestic nitrogen situation. It is believed the domestic productive capacity for this material will exceed 500,000 tons before the end of 1931. The consumptive demand for sodium nitrate for industrial and chemical purposes is probably about 200,000 tons, which leaves, let us say, 300,000 tons of domestic production to meet agricultural needs. If only past practice be considered, then normal agriculture might be some 400,000 tons short of the domestic material. The older products which will compete for this market are imported nitrate of soda, nitrate of lime and ammonium sulphate; and perhaps Nitrochalk or urea among the newer synthetic materials.

Statistics show that the agricultural use of sodium nitrate is approximately 80 per cent in the form of top-dressing or side-dressing materials and only 20 per cent in the form of home-mixed and factory-mixed fertilizers. With the wide discrepancy in price that now prevails between sodium nitrate and ammonium sulphate (including other similar nitrogen carriers), it is apparent that the amount of nitrate to be used in these mixed fertilizers will be still further decreased, its place being filled by the other forms of nitrogen. This represents a possible total of 140,000 tons of nitrate.

Use of ammonium sulphate as a top-dressing material has been expanding. Approximately 100,000 tons was used for this purpose in 1929. When properly employed there seems to be no doubt among authorities as to its suitability as a general top-dressing material. Agronomic research has shown that the use of ammonium sulphate causes an increase in soil acidity, but, on the other hand, the results of many years of field experiments (Ohio, New Jersey, Alabama, and Rhode Island agricultural experiment stations) demonstrate that when this acid residue is counteracted or neutralized with the appropriate amount of lime, plant growth and crop results show ammonium sulphate to give as good results as any non-acidic nitrogen carrier. In general, for a lime-deficient soil, the proper addition has been found to be 1.2 tons of ground limestone per ton of ammonium sulphate. This is equal to 0.06 tons of limestone per unit of nitrogen.

Making an allowance for the correction of soil acidity by liming, assuming that finely-ground limestone may cost the farmer as much as $9 per ton delivered at the farm, it figures out that sodium nitrate and ammonium sulphate are on an equal competitive basis (as far as agricultural results are concerned) when they are both selling at the same total price per ton. There is thus a wide margin of economy to be effected in top-dressing practices in this country.

Table III—Distribution by Products of Imported Nitrogen

	Short Tons of Nitrogen Content	Per Cent of Total
Nitrate of Soda	150,000	70
Cyanamide	30,000	14
Ammonium Sulphate, Miscellaneous Ammonium Salts, Urea, etc.	12,000	7
Calcium Nitrate	4,000	2
Cyanides	6,000	3
Nitrogenous Fertilizer Mixtures	8,000	4
Total	210,000	100

Anhydrous ammonia is the other nitrogen product which statistics show is very much on the increase as respects introduction into the fertilizer field. The direct addition of ammonia to superphosphate, neutralizing its acidity and adding nitrogen to the fertilizer at an absolute minimum cost, is a development of the last three years. Probably some 40,000 tons of nitrogen will go into fertilizers in this form this coming year.

Newer Nitrogen Compounds Gain

Numerous of the newer forms of fixed nitrogen seem to offer promise. These are Nitrochalk or Calnitro (a mixture of calcium carbonate and ammonium nitrate), urea (entering the United States this year for the first time on a duty-free basis), and calcium nitrate (a product long known but which, since it has been marketed in shotted form of higher grade, has found increased markets in Europe and in this country).

These products, as present price quotations show, are all in the cheaper range of nitrogen carriers, approaching ammonium sulphate. Their use should, therefore, grow just as rapidly as farmers and experiment station leaders find them demonstrated to be efficient and convenient means of conveying nitrogen to the crop. We can regard these compounds along with ammonium sulphate as the cheap nitrogen carriers of the future. (Combination products containing both nitrogen and phosphorus

will be discussed in another section below under the heading of "mixed fertilizers.").

Phosphorus and Potash

At present, the fertilizer industry in the United States is built largely around the manufacture of superphosphate. The total production of superphosphate in this country is about 4,000,000 tons per year, of which 3,000,000 tons goes into mixed fertilizer and 1,000,000 tons is marketed as such. We are considering now only this latter quantity.

Ordinary superphosphate, when employed alone, is competitive only with "triple superphosphate" (which is manufactured by reacting phosphoric acid with phosphate rock). The cost of manufacture of phosphoric acid has hitherto been too high to permit these two products to sell directly on the same basis. Improvements in the manufacture of phosphoric acid, particularly by the blast furnace method, and the possible large-scale introduction of triple superphosphate manufactured therefrom, may change this situation. On the other hand, the ability of these acidulated phosphate materials to absorb and fix large quantities of synthetic ammonia in its cheapest form will probably lead to their lesser use alone, and will bring them into the category of "mixed fertilizers."

Legitimate foreign competition with our own phosphate rock industry is not an entirely impossible event. Occasional shipments of Morocco rock have actually been received in this country. There is probably no immediate danger from this source but, on the other hand, the menace of foreign shipments is an effective barrier to any appreciable increase in phosphate rock prices.

Our potash situation appears to be reasonably well stabilized. The American interests sell their production in the zone which gives them the most economically reached markets. The European syndicate dominates the remainder of the field. American production in California is being expanded, and in addition there is active development work in progress on the polyhalite deposits of Texas. If this latter venture should materialize, the United States would probably be quite independent of foreign sources of potash. On the other hand, tentative cost estimates as prepared by the U. S. Bureau of Mines, show that the exploitation of these Texas deposits is not likely to lead to a major decline in domestic potash prices.

Mixed Fertilizer Industry

This industry has met many discouragements. It has served repeatedly as a Congressional football and it has been characterized in many uncomplimentary ways. Investigations by the Federal Trade Commission, however, indicate the absence of any "profiteering" on the part of the large fertilizer manufacturers; in fact analysis of the composite balance sheets of certain of these companies demonstrates they have actually incurred large deficits since 1920. Millions of tons of fertilizer have been sold at less than the true cost of manufacture.

Nitrogen in Mixed Fertilizers—Although 30 per cent of the nitrogen sold for agricultural purposes is consumed separately as top-dressings and in home-mixed materials, recent developments indicate that this proportion will tend to decrease. Nitrogen (and phosphoric acid and potash as well) has always sold at a higher price in mixed fertilizer than in unmixed form, because the price of mixed fertilizer includes mixing costs as well as extra capital and sales charges. On the other hand, nitrogen prices have largely declined and there is a wide discrepancy in prices between the forms of nitrogen customarily used in top-dressings, as compared with the forms of nitrogen going into commercial mixed fertilizers. The margin against the mixed fertilizer should, therefore, decrease and the farmer should, in general, find it increasingly convenient and economical to apply the entire nitrogen requirements of the crop in the one application of mixed fertilizer at the time of planting.

Gain in Ammonium Compounds

Availability of adequate supplies of ammonium compounds, which are not subject to the danger of leaching in the soil, tends to favor increasing proportions of these nitrogen carriers in mixed fertilizer. The progress of this development is being favored by active research on the manner of fertilizer distribution, and by improvement of distribution machinery as now being carried out by the U. S. Department of Agriculture, as well as by numerous state institutions.

The previous analysis of the domestic nitrogen production situation has shown that, within the year, there will be an apparent excess domestic production of nitrogenous materials normally considered as major components in mixed fertilizer. From the production point of view these are the nitrogen compounds having the lowest cost of manufacture. Is the domestic nitrogen producer going to make the effort to distribute this excess nitrogen in the top-dressing field? This may mean high sales and educational expense in order to accomplish the program. On the other hand, the synthetic nitrogen manufacturer might decide it would be simpler to make the further capital commitments necessary to convert this nitrogen to the usual top-dressing forms, which would mean falling in with the innate conservatism of the farmer in order to make the marketing end of the problem easy. The farmer ultimately pays, of course, for having his pleasure accomplished, and the nitrogen producer places himself in the position of having to safeguard the additional investment.

Our domestic fertilizer industry is, as far as can be judged, not in danger of immediate or violent revision by radically new processes. The introduction of anhydrous ammonia has been a major step forward in fertilizer technology. Improvements in superphosphate and triple superphosphate manufacture are under way and show promise for the future. Fundamental changes in the potash industry are probably more remote. Conditions are such that the margin of earnings in the mixed fertilizer industry will continue at a low figure, and the hope of the industry lies largely in increasing the dollar turnover.

The present offers a peculiar situation as regards nitrogen, which is the major cost element in fertilizer economics. Domestic nitrogen development is at a branching of the ways. If the fertilizer companies take advantage of their particularly favorable situation and arrogate to themselves the marketing of the

It seems that here is an outstanding opportunity for the mixed fertilizer manufacturer to seize a permanent advantage. This nitrogen is available at the lowest prices in history. The technology of its incorporation into present fertilizer mixtures is simple. The agronomic efficiency of such means of employment of this increased nitrogen is apparently established and well demonstrated. The experiment stations should also be actively interested in this development, since this may be the cheapest way to make low cost nitrogen available to agriculture. The fertilizer manufacturer is already paying the complete manufacturing and sales expense of his goods. He can incorporate and distribute this additional nitrogen to meet the present total agricultural needs, at a cost to him of practically only the out-of-pocket expense represented by the wholesale purchase price of the nitrogen. The farmer likewise saves as respects both labor and handling expense.

$5,000,000 Saving to the Farmer

For the purposes in which top-dressings are absolutely and demonstrably necessary, an adequate domestic production is apparently available. For the other purposes. if the mixed fertilizer manufacturers and the experiment stations would sincerely join forces on a sound program, they should be able to show the farmer how he can obtain the maximum benefit from nitrogen at the lowest possible cost. These agencies might very reasonably save at least $5,000,000 of the farmer's yearly nitrogen bill—and this is without the fer-

unapportioned excess of domestic nitrogen production, they will have an opportunity to entrench themselves with profit, and to help in a major way in benefiting agriculture with cheap fertilizer. Inter-commodity competition in this industry would then not be a menace to its orderly development.

Likewise, the agricultural experimental stations and research institutions in the United States should take particularly careful account of present economic and manufacturing trends in the domestic fertilizer industry. These scientific institutions should be active in shaping the course of their research to keep pace with and furnish agricultural guidance for industrial development. Further, their province is leadership and education to guide the farmer into taking full advantage of changing conditions and to insure that his expenditures for plant foods are directed to give him the largest possible return with the best economy of money spent.

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tilizer manufacturer's sacrificing the normal trading profit in handling this additional nitrogen tonnage.

Triple Superphosphate New Factor

The chief process of "unlocking" phosphate rock, i.e., making available its P_2O_5 content, has remained essentially unchanged for 80 years. This refers to the standard method for the manufacture of superphosphate by reacting phosphate rock with sulphuric acid. Triple superphosphate manufacture is of recent growth, the process being essentially, first the manufacture of free phosphoric acid by the same basic reaction as is employed in the superphosphate process; and second, the reacting of this phosphoric acid with additional phosphate rock. Both of these processes use the same quantity of sulphuric acid per unit of phosphorus pentoxide thus made available.

Recently, announcement has been made of the commercial manufacture of triple superphosphate, for fertilizer purposes, by means of the blast furnace process for smelting phosphate rock and volatilizing phosphoric acid. Such figures as have been publicly disclosed indicate the process can operate within the competitive range of standard superphosphate manufacture. The major products of such manufacture would probably be triple superphosphate, ammoniated triple superphosphate and ammonium phosphate. The manufacture of the latter might possibly be conducted at coke oven plants to yield byproduct ammonium phosphate instead of the byproduct ammonium sulphate which is made at present.

Since the superphosphate industry is the largest consumer of sulphuric acid in the country, any change in process, or otherwise affecting this commodity, may have a far-reaching effect in the fertilizer industry. The price of sulphur may be an important factor in determining future competition between the various phosphoric acid manufacturing methods. As far as can be foreseen now, however, the blast furnace process for phosphoric acid will not normally be expected to make immediate serious inroads on the established superphosphate industry.

Other processes for the unlocking of phosphate rock have been proposed, such as, for instance, treatment of the rock with nitric acid, oxides of nitrogen and so on. These processes have, to date, not progressed beyond the laboratory stage.

Concentrated Fertilizers

In recent years, coincident with the emphasis placed on inorganic nitrogen as displacing the natural organic forms, greater attention has been paid to the more concentrated types of fertilizer materials. The chief of these newer products already used in a large tonnage way are: triple superphosphate; anhydrous ammonia and urea; ammonium phosphate (mono or di) and the various corresponding mixtures with ammonium sulphate; and finally incorporated mixtures made of the ammonium phosphates and potassium and ammonium nitrates or chlorides, such as the various materials of the "Nitrophoska" type.

All of the above substances contain a total of 40 per cent plant food or better, which contrasts with the average plant-food content of about 16 per cent in the standard commercial grades of fertilizer now being marketed. As relates to agriculture in the United States, it is believed to be correct to say that, except for the purpose of enriching and raising the grade of lower analysis standard fertilizer mixtures, the remaining use of these materials for application as such has been practically only of a magnitude to be classed as experimental.

With the exception of anhydrous ammonia, these concentrated fertilizers tend to be "premium" products and sell, f.o.b. factory, at rates per unit of plant food above standard materials. Aside from anhydrous ammonia, and with perhaps the further exception of urea and of certain phosphate products (specifically, triple superphosphate made from furnace phosphoric acid), it is almost inevitable that these products should sell at higher than standard base commodity prices because of the extra processing costs involved in their manufacture. Also, sales expense on these newer products tends to be high. The offsetting factor, of course, is the lower freight and handling expense for the more concentrated materials.

A further complicating factor in the use of the more concentrated materials is the general unreliability of the present agricultural machinery for making the uniform and even distribution of the small quantities of these concentrated materials that is required. Until this difficulty is solved, the growth of separate direct markets for these concentrated goods will be retarded. However, there is a permanent and steady tendency toward greater concentration of plant food in a considerable proportion of fertilizer products.

Fertilizer Acidity Needs Study

Another aspect of the situation also merits consideration. More attention and appreciation of soil acidity, and also toxicity effects resulting from the use of unbalanced combinations of plant-food constituents, has been evident in the last few years. The soils in the South and Southeast (which are the major fertilizer consuming sections of the country) are inadequately buffered against acidity; and it seems only a reasonable conclusion that the fertilizer mixtures of the future should contain enough liming material to compensate for the acidity effects of the ammoniacal or organic forms of fertilizer nitrogen used. These same soils are also notably deficient in calcium, and in some cases, a deficiency in magnesium and sulphur exists.

High applications of fertilizer nitrogen are practical if at the same time an adequate supply of magnesium and sulphur is available to the plant. Commercial fertilizer mixtures of the present average grade, in general, supply these deficiencies. However, the maintenance of an adequate calcium content of the soils is not assured by some of the present "concentrated fertilizers." This undoubtedly is one of the reasons why the ammonium phosphates have not made more headway in fertilizer practice in this country. On the other hand, one would expect that between ammonium phosphate and ammoniated triple superphosphate, the latter should be preferred agriculturally first, because of the lower manufacturing cost, and second on account of the desirable lime content.

Farmer Education a Requisite

If the farmers of the South and Southeast could be educated to the basic economy of an adequate liming program (dolomitic limestone preferably), then the major objections to present forms of concentrated fertilizers would disappear. The farmer, however, does not see the benefit of lime directly demonstrated by immediate response or crop growth. Therefore, he is reluctant to spend money for lime as such. On the other hand, the fertilizer industry and the experiment stations should foster this lime program; and further, they should insure that the lime or calcium content in the fertilizer materials offered to the farmer is not dangerously reduced.

Promise of Cheap Phosphoric Acid Foreshadows New Markets

By R. S. McBride
Assistant Editor, Chem. & Met.

CHEAP PHOSPHORIC ACID appears to be a certainty for the early future. But the word "cheap" is a relative and somewhat ambiguous term; and "early future" may not be interpreted too literally, especially in view of the present unsettled condition of the several branches of industry which are dealing with this important industrial chemical. No one can say with any certainty today which of the three major processes now in active development is likely to give us the cheapest phosphoric acid, or whether possibly all three will succeed and the combined effort result in a veritable flood of this acid, which offers such interesting possibilities for the future, provided that it can be made at low enough cost to displace its competitors and encourage new uses.

The three systems of manufacture referred to above are the wet process, the blast-furnace process, and the electric-furnace process. Each has its ardent advocates and each its sharp critics. An impartial, and somewhat credulous, observer is, therefore, rather disposed to look with optimistic hope on the future of all three. Certainly each has backers of high repute, ability, and ample financial resource to inspire considerable confidence.

The first successful dry method for large-scale manufacture of phosphoric acid on any basis that suggested application in the major field for phosphates—namely, the fertilizer industry—was the electric-furnace development. Early stages of this undertaking were carried out by Carothers, under the auspices of the Bureau of Soils, and the commercialization was achieved at Anniston, Ala., where there is in operation today one of the largest producing units giving phosphoric acid. Numerous variations of this process have been undertaken with little commercial success, and the Anniston process has been extended to European industry with the co-operation of its American backers.

Following close on the heels of the electric-furnace development, under government auspices came the first experimental-scale, fuel-fired furnace, burning oil. The work with this equipment at the Arlington (Va.) station of the Bureau of Soils resulted in several publications which aroused sufficient interest to result in a number of semi-commercial undertakings. The first large-scale plant that can be called strictly commercial in scale and operation was built near Nashville, Tenn. That blast-furnace unit has very recently been superseded by another furnace owned and operated by the same company. The second furnace is said to improve materially on the performance of the first; and it probably is the largest single operating generator of phosphoric acid working anywhere in the world today.

Experimentation has been continued by the government under the Bureau of Chemistry and Soils, and an experimental furnace of quite different design than that at Nashville is functioning at the Washington station of the Bureau. Certain companies have indicated their intention to take advantage of the results of this experimental furnace plant for the erection of commercial furnaces if the results obtained are as favorable as now appear likely.

In connection with the development of the blast-furnace type of phosphoric-acid plant it is of interest to note that a single furnace of size comparable with a modern iron blast furnace would produce enough phosphoric acid to correspond to nearly 20 per cent of

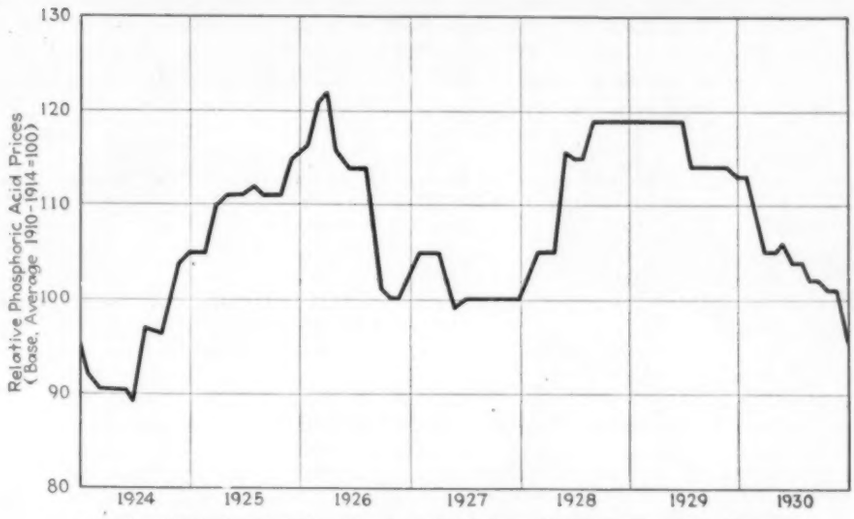
Important Corporate Factors in Development of Phosphoric Acid and Phosphates

Swann Chemical Company, Federal Phosphorus Division	Operates electric furnace, making phosphoric acid and other products; Anniston, Ala.
Victor Chemical Works	Operates blast furnace making phosphoric acid and other products; Nashville, Tenn.
Coronet Phosphate Company	Owns blast furnace for phosphoric acid manufacture (affiliation with German Metallbank and Metall-Gesellschaft reported), export from Tampa district proposed.
The Dorr Company	Installs Dorr wet-process plants; developing Dorr-Liljenroth processes.
Consolidated Mining & Smelting Company	Reported to be installing first American Dorr-Liljenroth process plant, at Trail, B. C., for making phosphoric acid.
American Cyanamid Company	Building "giant phosphoric-acid plant" near Tampa, Florida; interested also through Ammo-phos and other possibilities for ammonia and cyanamide utilization.
Ober Chemical Company	Has developed Oberphos process for pressure treatment of phosphate rock with acid.
Anaconda, International-Agricultural, Virginia-Carolina, Armour Fertilizer Works, and numerous other fertilizer companies	Interested in wet-process acid for double and triple superphosphate making; potential users of new processes or customers for acid made by furnace methods.
Phosphate Products Corporation	Manufactures phosphoric acid and phosphates using wet and modified pyrolytic processes.
The Koppers Company	Interested in phosphoric acid as carrier for ammonia from coke works, both owned and built for others; reported participating in Oberphos development.
The Barrett Company	Interested as marketer of ammonia products for coke works and for affiliated companies.
Atmospheric Nitrogen Corporation, DuPont Ammonia Corporation, and Mathieson Alkali Works	Interested in phosphoric acid development as carrier for ammonia made by synthetic plants owned directly or by affiliated or subsidiary companies.
Chemical companies, including Rumford, Warner, General, Grasselli, Calumet, and others	Interested through desire for cheap phosphoric acid to make phosphate chemicals for other than fertilizer purposes.
Tennessee Products Company	Manufactures ferrophosphorus; interested in new furnace developments affording ferrophosphorus byproduct competitive with its present products.
Oldbury Electrochemical Company	Manufactures phosphorus and small quantities of ferrophosphorus; is interested in new potential competition.
American I. G. Chemical Company	American agency of I.G., interested in import of Nitrophoska and other concentrated fertilizer materials containing phosphates; potential American producer also.

the entire requirement of the United States for phosphate fertilizers. Hence, five or six such furnaces, if successfully operated, could supplant all other sources of phosphate; of course, assuming no increase in requirement. Such a speculative calculation, though interesting, must not be taken too seriously. It merely indicates the important fact that no large number of big furnaces is likely to be needed, and that either the commercial unit ultimately resulting will have to be much smaller than in the case of pig-iron furnaces, from which most of the engineering designs are being adapted, or else we must expect an extremely limited number of producing companies and plants.

Wet Processes for Phosphoric Acid

Manufacture of phosphoric acid from sulphuric acid and phosphate rock by the wet process continues to be successfully applied with some important improvements that have been incorporated in the industry very recently. The major backers of developments in this field appear to be concentrating their attention on the Dorr-Liljenroth process. This is not a single process, following unvaryingly a single procedure to a single group of products. Rather, it is a group of processes which may be carried on in proportions to yield the optimum over-all results commercially. The normal products are chemicals suitable for "concentrated fertilizers." Incidentally, however, the process can give phosphoric acid which is directly competitive with that made either with electric- or with blast-furnace equipment. Where a double superphosphate or a triple superphosphate is the desired product, instead of the ordinary 16-per cent grade of "super," some variation of these wet-process procedures appears to have very considerable advantage. It is not so evident, however, that a similar advantage competitively attaches to wet procedures when it is desired to make high-purity chemicals such as mono- or diammonium phosphate or other phosphate chemicals for industrial application outside the fertilizer industry. Very often for these latter purposes, the higher purity of phosphoric acid made by a furnace volatilization procedure becomes a determining factor in the choice of process.



Trend of Wholesale Phosphoric Acid Prices, 1924 to Present; Base, Average 1910-1914=100 ***(Courtesy N. Y. Potash Export My.)***

Wet Versus Dry Processes

Not a negligible factor in the competition between furnace and wet processes is the commercial consideration of present equipment and materials owned by the interested phosphate concerns. Obviously, those large companies of the fertilizer industry that are already equipped with sulphuric acid plants, for which they would have no need if they turned to a furnace process, are going to look with favor on the improved wet procedures. In fact, the availability of cheap sulphuric acid, or the ownership of a sulphuric acid plant otherwise useless, will often be a determining consideration, without regard to the possible lower apparent cost per unit of P_2O_5 made by volatilization in a furnace, especially if one is to compare costs on a basis including capital charges only for new investment.

On the other hand, large chemical engineering companies that are primarily interested in making chemicals, or in securing a carrier for ammonia, may find great advantage in the furnace processes, since these yield a grade of acid equally well adapted to pure chemical making and to crude fertilizer-chemical manufacture. Furthermore, it should not be forgotten that these chemical companies are today apparently in a much better financial position to carry out new development work or to secure funds needed for new investment than are most of the companies which are now engaged primarily in the fertilizer business. The latter group of companies has, of course, suffered considerable financial difficulty, due to the unprofitable period which has prevailed in their entire industry so much of the time since the close of the World War.

Competition With Sulphuric Acid

Phosphoric acid as a carrier of ammonia is directly competitive with sulphuric acid, and to some degree with some other acids. The production of cheap phosphoric acid by either electric, blast-furnace or other thermal method promises to furnish this chemical on a basis that will make it a serious competitor in coke and gas works as an absorbent. It would have like value at synthetic ammonia plants, of course. At the present time more than half of the direct cost of ammonium sulphate frequently is incurred simply by the purchase of sulphuric acid. If phosphoric acid can be substituted in a way to carry its own cost through increased value of the product, then the coke manufacturer who today finds ammonia an almost profitless by-product will welcome it most cordially. The technique for substituting phosphoric acid for sulphuric acid in the saturator, and the making of ammo-

Exports of Phosphates From the United States*

(Quantities in Long Tons, Values in Dollars; 000 Omitted)

	High-Grade Rock		Land-Pebble and Other		Superphosphates	
	Quantity	Value	Quantity	Value	Quantity	Value
1923	194	2,478	633	3,295	42	534
1924	151	1,814	668	3,307	46	589
1925	159	2,283	711	3,395	66	989
1926	104	1,196	645	3,240	64	937
1927	129	889	789	3,843	108	1,615
1928	90	616	809	3,837	89	1,510
1929	67	473	1,075	4,914	85	1,489
1930	70	475	1,200	5,350	115	1,650

Imports of Phosphates Into the United States*

(Quantities in Long Tons, Values in Dollars; 000 Omitted)

	Bone Ash, Dust, Meal and Other Animal Carbons		Other Phosphates	
	Quantity	Value	Quantity	Value
1923	56	1,733	11	150
1924	22	707	23	258
1925	25	724	11	190
1926	47	1,380	22	282
1927	54	1,541	47	561
1928	82	2,566	50	501
1929	56	1,624	49	525
1930	60	1,500	36	420

*Data from U. S. Department of Commerce, except for 1930, part of which figures are based on *Chem. & Met.* estimates.

Phosphate Rock Production of Principal Producing Countries*

These Seven Areas Produce Approximately 96 Per Cent of World Output†

(Metric Tons, 2,205 Lb.; 000 Omitted)

	Algeria	Egypt	Makatea Island	French Morocco	Nauru and Ocean Islands	Tunisia	United States
1913	377,934	104,450	82,056	.....	250,000	2,284,678	3,161,147
1914	355,140	71,945	72,925	.....	.....	1,395,630	2,777,916
1915	225,891	82,998	71,724	.....	.....	1,170,033	1,865,124
1916	389,211	125,008	39,285	.....	70,000	1,041,204	2,014,196
1917	234,825	115,732	32,250	.....	202,000	576,000	2,625,757
1918	198,539	31,147	40,000	.....	155,000	862,494	2,530,729
1919	271,162	29,365	40,000	.....	115,000	1,075,214	2,308,442
1920	502,614	114,813	32,000	.....	392,000	1,075,180	4,169,839
1921	398,800	122,024	60,000	33,000	370,000	1,800,000	2,097,146
1922	484,304	60,220	71,350	96,397	367,000	2,117,650	2,456,683
1923	467,384	25,370	74,230	225,395	318,794	2,338,000	3,054,955
1924	681,136	87,869	89,611	461,582	459,162	2,391,000	2,913,817
1925	815,116	106,808	81,061	692,181	478,278	2,691,000	3,537,702
1926	929,355	232,008	127,177	882,821	398,059	2,568,000	3,261,496
1927	919,108	279,389	135,666	1,400,000	633,345	3,075,000	3,221,589
1928	875,947	200,563	136,306	1,337,079‡	509,970	2,789,000	3,557,604
1929	747,674	215,311	242,990	1,608,249‡	512,265	2,511,000	3,889,881

*Data from U. S. Bureau of Mines.

†France, Belgium, and Japan formerly important although none of these exceeded 3 per cent of world production at any time.

‡Shipments including exports: 1928, 1,323,293 tons; 1929, 1,591,933 tons.

nium phosphate instead of ammonium sulphate, has not been fully worked out through any extended commercial trials in the United States. However, experimental work is said to have been done on a sufficient scale to demonstrate that this is a commercially practicable development which will not largely increase operating costs and not at all decrease completeness of ammonia recovery. The main deterrent to commercial development is, of course, the present high cost of phosphoric acid.

One very important consideration should, however, be noted in this connection. Complete success has attended the use of ammonia, either as gas or as liquor, for direct ammoniation of superphosphates in the fertilizer works. With the modified methods for testing which are now being authorized for official use through preliminary, and prospectively final, action of the Association of Official Agricultural Chemists, full credit can be expected in the finished fertilizer, not only for the ammonia so used but also for the P_2O_5 contained in the phosphate treated. This development affords to ammonia from the coke and gas works a new direct market, which suggests the probability that a great deal of the ammonia made in these plants probably will be marketed as liquor or in anhydrous form rather than as sulphate. To the extent that this development does progress there will, of course, be a restriction of the area in which phosphoric acid may supplant sulphuric acid. The consequences in restricting use of sulphuric acid are, however, equally significant.

Cost of Phosphoric Acid

The probable cost of phosphoric acid made by either wet or furnace processes has been the subject of much discussion and calculation, and of some more or less complete published articles. However, there are at least three major difficulties involved in such cost estimating: The proper magnitude of credits for byproducts is still quite uncertain. In the case of furnace plants particularly, the capital charge necessary per unit of acid made per day remains still largely a matter of guess. Data are still unavailable for any accurate forecast as to either the percentage recovery which is possible, or the fuel requirement of fuel-fired furnaces of the large capacity probably necessary as an ultimate development to insure commercial success. A brief discussion of these three points will make it clear why at the present time estimates range all the way from $20 to $140 per ton of P_2O_5 as the probable or the possible future cost of making phosphoric acid.

When making phosphorus, phosphorus pentoxide, or phosphoric acid in either electric or blast furnace, it is also necessary to make a substantial quantity of ferrophosphorus. This alloy commands a favorable price in limited quantities, but the market is not capable of large expansion. Hence, it is doubtful whether any credit of significant size can properly be taken if one is calculating on the basis of a big blast furnace for phosphoric acid manufacture. Such credit has by some been claimed to amount to as much as $7 to $10 per ton of P_2O_5 produced as phosphoric acid; others believe that a disposal charge should be included instead of a credit. Hence the magnitude of the credit or charge introduces a substantial uncertainty in any cost system applicable to the various furnace methods.

With the older Dorr process and with any one of the variations of the Dorr-Liljenroth process, the estimates of cost vary widely, according to whether calcium sulphate and calcium carbonate are either made and discarded or become useful byproducts. Thus even in the modern wet-process plant one must range far afield in appraisal of markets for things other than phosphoric acid before he can accurately determine the probable net cost of the principal product.

Furnace Considerations

Cost of building an electric-furnace plant is well known to the backers of that process. Its efficiency and its productive capacity also are well known, so that unit capital costs are rather definitely determinable. Corresponding figures for the required total investment in a blast-furnace plant, including precipitators, storage, and the gas-cleaning and gas-handling facilities are also easily forecast. The long experience of American pig-iron blast-furnace builders affords much data of a thoroughly dependable sort. However, these data applicable to pig iron give no clear indication as to how much coke can safely be burned per hour in a furnace of this type when making phosphoric acid, and hence no thoroughly reliable basis for gaging the acid-making capacity. A superintendent operating such a furnace would have to determine for himself whether he could safely operate with blast at 800, 900, or at 1,000 deg. C., and furthermore, whether he could safely place a burden on the furnace corresponding to 5 lb., 4 lb., or perhaps even 3 lb. of coke per pound of P_2O_5 evolved and recovered. If his skill and his nerve should enable him to operate with low coke-to-acid ratio and with high blast temperatures, he would then have extremely low costs per unit of acid made, because the dollars per day for labor and capital charge, which are practically constant regardless of output, would be spread over so much greater tonnage. The same line of argument, of course, applies with reference to calculation of cost of rock and cost of other materials and their preparation for smelting. Each of these items creates costs per pound of acid made that depend on the completeness of recovery of P_2O_5 from the rock and the efficiency of fuel use in the stack.

A blast furnace, it should be noted, uses carbon not only for reducing the phosphate but also for producing heat, whereas all heat is produced by electricity in the electric furnace. Recovery of P_2O_5 from the blast-furnace gases is more of a problem than from the electric furnace, due to the larger volume of gases to be handled. This distinction, of course, is important in

Consumption of Phosphate Rock in the United States*

(Long Tons)

	Marketed Production	Imports	Exports	Apparent Consumption—Total	Apparent Consumption—Domestic Rock
1919	2,271,983	34	378,731	1,893,286	1,893,252
1920	4,103,182	63	1,069,712	3,034,333	3,034,270
1921	2,064,023	3,535	733,312	1,334,248	1,330,713
1922	2,417,883	5,890	719,294	1,704,479	1,698,589
1923	3,006,706	6,725	827,551	2,185,880	2,179,155
1924	2,867,789	16,098	818,773	2,035,114	2,049,016
1925	3,481,819	2,735	870,200	2,614,354	2,611,619
1926	3,209,976	17,378	748,963	2,478,391	2,461,013
1927	3,170,699	28,195	918,211	2,280,683	2,252,488
1928	3,457,339	25,817	898,764	2,604,387	2,558,575

*Data from U. S. Bureau of Mines.

comparison of both construction and operating costs.

It has been suggested that any existing pig-iron blast furnace might readily be converted to phosphoric acid operation if desired. By the development and addition of facilities for handling gas and phosphorus, phosphorus pentoxide, and phosphoric acid, including a Cottrell precipitator, such conversion could doubtless be accomplished without serious engineering difficulty. Most of the phosphoric acid blast-furnace development thus far has, in fact, proceeded almost entirely on the assumption that the present iron furnace should be taken as a model. The more radical engineers believe, however, that an entirely new type of furnace would work equally well, if not much better, particularly one with very low stack and with hot-blast stoves built on much more efficient principles. Such new types of equipment would offer the advantage of lower capital investment per unit of furnace capacity, assuming, of course, that they functioned as successfully as their proponents anticipate.

In 1929 there was presented before the fertilizer section of American Chemical Society a paper by F. H. Royster and his associates, estimating that under favorable conditions the cost of phosphoric acid at a single blast-furnace plant, operating to produce this product at the rate of 230 to 360 tons per day, would be from $20 to $27 per ton of P_2O_5 contained in the acid. This cost included rock, fuel, flux, and other materials, all furnace labor including superintendence, and the direct capital charge on the furnace and accessory equipment. It did not include any allowance for general management or for sales, nor any profit on operations beyond the interest, repairs, and depreciation on the furnace and accessory equipment, which capital cost was calculated on the basis of about 20 per cent per annum. This figure is very much lower than anyone else has offered, and may well be a subject for skepticism. It was frankly presented by its proponents as an objective toward which they believe the industry might work and which it might approach with some degree of certainty over a period of years. More conservative estimates indicate that production of acid at $40 per ton of P_2O_5 is the best that may be expected in the early future. Even this substantially higher figure is decidedly below anything as yet attained industrially or on a semi-industrial scale. Estimates as to present commercial practice have indicated to the author a range from $85 to $140 per ton of P_2O_5 in the acid.

Superphosphate is commonly quoted at $8 to $10 per ton of 16 per cent grade. This corresponds to $50 to $62.50 per ton of contained P_2O_5. These prices are, of course, sales prices and include management and selling expense as well as any profits that may be made. Hence, to be strictly competitive on the basis of equivalent plant-food value, the phosphoric acid must be had at a corresponding figure. If such a figure were attained in the deliveries of phosphoric acid at, for example, a synthetic ammonia plant or a byproduct coke works, then the acid could be used as an ammonia carrier with the assurance that the phosphate content of the product would add sufficiently to its value so that the acid purchased would represent approximately zero net cost. In other words, the use of phosphoric acid as a carrier for ammonia would save substantially the entire cost of sulphuric acid, because the ammonium phosphate would be worth more than the ammonium sulphate now produced by an amount equal to the cost of the phosphoric acid.

Not precisely the same quantitative relationship would apply in making ammonium phosphate through a Dorr-Liljenroth procedure, but a very close parallelism of costs does follow. Generally speaking, therefore, the development of any scheme which will furnish phosphoric acid or concentrated phosphate either by furnace or wet processes for $50 to $60 per ton of contained P_2O_5 means that the product is free to compete with and to replace much of the superphosphate now employed as a fertilizer. This replacement, contingent upon such low-cost acid, will doubtless come to pass in many parts of the country, but just how soon this will happen cannot be safely forecast by anyone. Simultaneously there will be interesting parallel developments in the field of phosphates made for chemical purposes.

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Phosphate Rock in 1930

PRODUCTION of rock and making of superphosphate continued during 1930 to be responsive to the same factors that affected the fertilizer industry, discussed elsewhere in this issue. There have remained, however, a few factors peculiarly significant with reference to our world relations in the field of fertilizer phosphates that deserve separate notice.

North African phosphate development under French and Italian colonial or mandate control was rapid in the immediate post-war years. This development reached a plateau of substantially constant activity, largely because of the limit of buying power for fertilizers in Europe. Since 1927 there has been but small increase. Figures for the first part of 1930 show a large increase in Morocco, about 35 per cent; a modest increase in Tunisia, about 10 per cent; and substantially no change in Algeria. With prospective further development of European agriculture it is to be expected, however, that these North African resources will find wider application in Europe. Not only the close political affiliation but also the geographic proximity, give marked advantage; and the employment of convict labor in many areas affords low-cost production with which the United States cannot hope to compete.

Threatened import of phosphate rock into the United States, especially from Morocco, appears to have been successfully thwarted. Through a combination of anti-dumping and convict-labor regulations, the Treasury Department is virtually compelled to prevent entry of such rock at price levels that would make it a matter of serious concern to American producers. It is hoped by the industry that the continued application of these two types of restriction will be adequate to care for their needs.

Superphosphate Production in the United States

Data from U. S. Department of Commerce
(Net Tons; 000 Omitted)

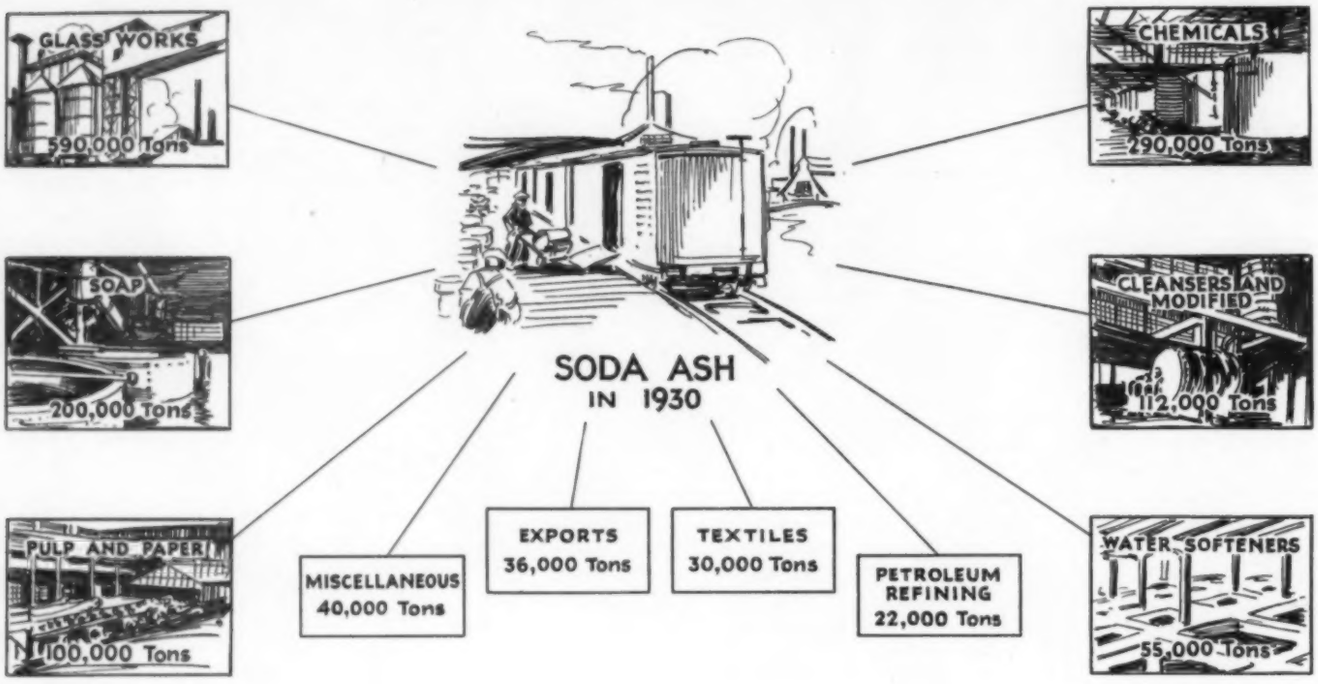
		Produced	Sold or Shipped*	Final Stocks on Hand
1922	1st half	1,199	2,085	.....
	2d half	1,589	978	1,690
1923	1st half	1,758	2,230	1,111
	2d half	1,609	807	1,772
1924	1st half	1,584	2,571	966
	2d half	1,666	809	1,683
1925	1st half	1,800	2,556	959
	2d half	2,046	994	1,917
1926	1st half	1,993	2,566	1,349
	2d half	1,806	970	2,036
1927	1st half	1,564	2,406	1,172
	2d half	1,903	1,040	1,948
1928	1st half	2,261	971	932
	2d half	2,228	313	1,462
1929	1st quarter	1,051	513	1,045
	2d quarter	1,074	540	876
	3d quarter	1,028	195	1,123
	4th quarter	1,142	132	1,313
1930	1st quarter	1,242	508	940
	2d quarter	1,222	555	894
	3d quarter	1,029	167	1,259

*Data through 1927 are for sales; 1928, 1929, and 1930 are for shipments.

Byproduct phosphatic slags are, of course, an important factor in European phosphate supply; but diminished operation at steel plants during 1930 has occasioned a decline in their production.

Research during the past year has contributed several improvements in the United States. Among them are the Oberphos process for treatment of rock with acid under pressure; the new tentative regulations for analysis of superphosphate that has been ammoniated, which when fully applied will give credit for much more of the P_2O_5 present in this modified product; further knowledge regarding which types of rock are worthy of consideration for beneficiation by tabling or other ore-dressing methods (some types, because of the intimate association of phosphate and gangue minerals, are not susceptible of beneficiation); and a new threat of competition with sulphuric acid, as is discussed on page 29.

In general, one can conclude that 1930 has not been a particularly happy year for the phosphate industry and that 1931 does not promise any striking improvements in prosperity.



Price and Process Determine Choice of Alkalis

Editorial Staff Review

IN CONSIDERING inter-commodity competition in the case of alkalis, it is the purpose of the present article to discuss lime, soda ash, caustic soda, ammonia, and borax. No attempt will be made to deal with other alkaline products such as tri-sodium phosphate, modified sodas, and sodium metasilicate. These products are now used chiefly for industrial and household cleansing purposes and their use depends primarily on their properties of saponification and emulsification. Borax might also be eliminated for these reasons, but has been included because of its possible competition with soda ash in the latter's most important market, the manufacture of glass.

Question as to what alkali should be used for a specific purpose depends not only on the relative cost of the various alkalis but also on the problems involved in the particular chemical process and the particular product which is to be made. In certain cases these latter factors may be of primary importance and therefore the determining ones, rather than the price itself. For certain processes, for example, lime is very often desired, not because it is the cheapest alkali available but because of its property of forming insoluble precipitates with certain acids, particularly sulphuric. This property is frequently utilized in order to remove as insoluble calcium sulphate the sulphate radical resulting from the use of sulphuric acid in the process. In the case of numerous products where a salt of a particular base is desired, the selection of alkali for the particular purpose is restricted.

Other factors which must be considered are the chemical engineering problems involved in the process and inherent in the type of equipment required. All the alkalis discussed here are solid products, with the exception of ammonia, which is a gas at ordinary temperatures and pressures. The choice between the solid alkalis will not likely involve any material changes in equipment and engineering details. But the substitution of a gaseous product such as ammonia usually will require modifications in design and equipment. The economies, therefore, in changing from a solid to a gaseous alkali must be sufficient to offset any expense incident to change in equipment.

Other things being equal, the ultimate choice of the alkali to be used will depend on the price paid for equivalent alkali content. Table I shows a comparison of the basicity of the several alkalis in terms of percentage of equivalent Na_2O. The table also gives the relative prices per short ton of equivalent Na_2O based on the market prices of the individual alkalis. If we examine the data concerning the cost of equivalent Na_2O content, it becomes evident that lime is the cheapest alkali, followed in order by soda ash, ammonia, caustic soda, and borax.

Estimated Distribution of Soda Ash Sales In the United States

Consuming Industry	1928 Tons	1929 Tons	1930 Tons
Glass Works	620,000	672,000	590,000
Soap	210,000	213,000	200,000
Chemicals	225,000	335,000	290,000
Cleansers and Modified	130,000	125,000	112,000
Pulp and Paper	100,000	110,000	100,000
Water Softeners	63,000	60,000	55,000
Petroleum Refining	23,000	26,000	22,000
Textiles	36,000	40,000	30,000
Exports	30,000	40,000	36,000
Miscellaneous	45,000	47,000	40,000
Totals	1,482,000	1,668,000	1,475,000

Estimated Distribution of Caustic Soda Sales In the United States

Consuming Industry	1928 Tons	1929 Tons (Revised)	1930 Tons
Soap	97,000	108,000	100,000
Chemicals	82,500	135,000	100,000
Petroleum Refining	98,000	121,000	105,000
Rayon	82,000	115,000	110,000
Lye	32,000	25,000	22,000
Exports	59,000	60,000	63,000
Textiles	37,500	42,000	30,000
Rubber Reclaiming	35,000	40,000	20,000
Vegetable Oils	11,000	11,000	10,000
Pulp and Paper	33,000	45,000	42,000
Miscellaneous	31,000	48,000	38,000
Totals	598,000	750,000	640,000

Lime has long been the cheapest industrial alkali and one would naturally think that it would have been utilized to its fullest extent in the chemical industry. However, this seems not the case in this era of rapidly shifting chemical processes. Apparently, in the early stages of the commercial development of new processes, it is often necessary to use higher priced alkalis, which through later improvements in technical details may then be replaced by a cheaper alkali, such as lime. A case in point is the recent substitution of lime for caustic soda in the manufacture of ethylene glycol. This change has naturally resulted in throwing additional quantities of caustic soda on the open market, with the inevitable result of weakening caustic soda prices. Such an example is typical of the substitution of a cheaper alkali and the possibly far-reaching effect on economics and market situation in the alkali field which may result.

Availability of plentiful supplies of anhydrous ammonia at cheaper prices has focused attention on the possibilities of using this product to replace some of the better known industrial alkalis. From the prices shown in Table I ammonia apparently is a cheaper alkali than caustic soda and therefore its possible substitution for the latter is suggested. To place caustic soda on an equal price basis per unit of alkali, caustic soda would have to sell at $45 per short ton. In view of the weakness of caustic soda prices in the present contract season, it is believed that this material has sold at such a price or lower, so that at the present time caustic soda and ammonia are on a basis of price equality, f.o.b. works. Freights to consuming points would have to be taken into consideration, since 1 lb. of ammonia is equivalent to about 2¼ lb. of 76 per cent solid caustic soda.

If ammonia were to be used instead of caustic soda, the question of the type of equipment which would be required would be an important factor in determining competition between these two products. The use of ammonia gas will require closed systems to prevent losses; and if it is to replace the principal solid alkalis now in use, it will demand new types of equipment in many cases. Since the production and distribution of ammonia are chiefly in the hands of large chemical companies with adequate financial resources and experienced technical personnel, these problems undoubtedly can be solved as they arise. However, the advantages must be sufficient to justify the capital expenditure where any changes in equipment are involved. So far, ammonia as an alkali has been used principally to prevent corrosion in the condensing side of petroleum refining equipment. At the present time petroleum refining takes about 15 per cent of the caustic soda sold. This field appears to be the most promising immediate outlet for ammonia as an alkali.

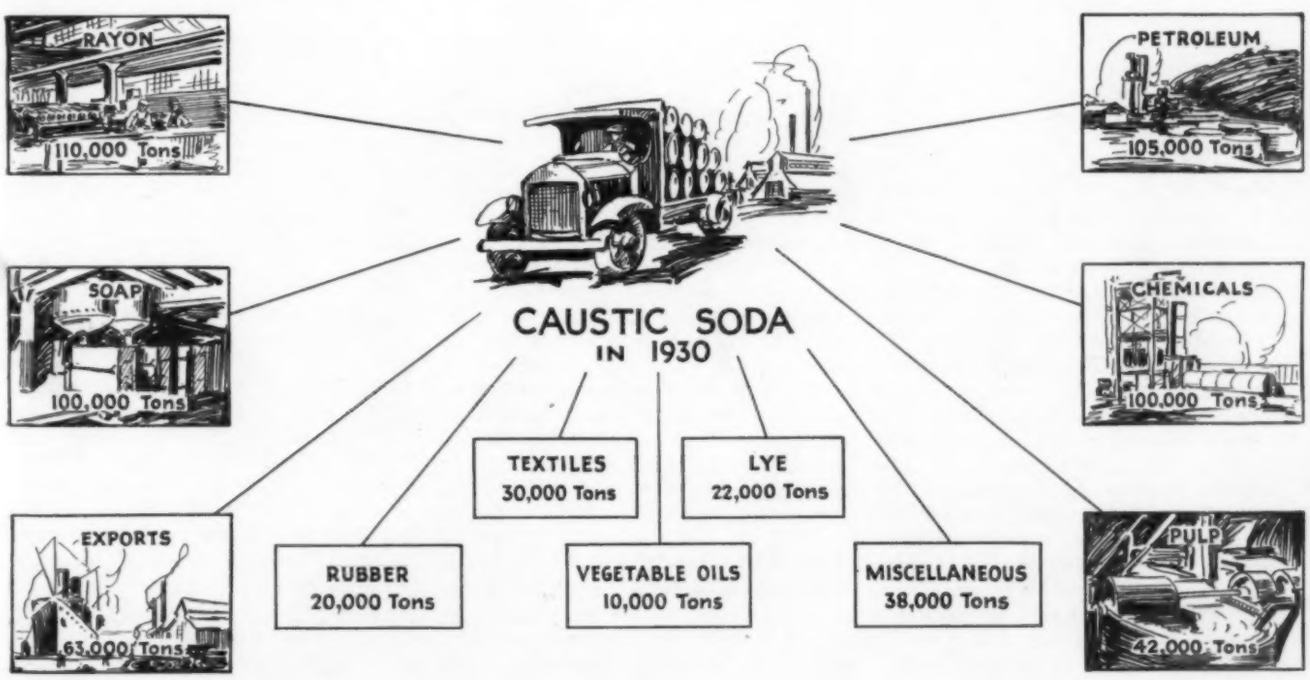
Other important outlets at present for caustic soda are soap, rayon and general chemical uses, each accounting for about 15 per cent of the caustic soda sold as such. The soap industry also consumes about 13 per cent of the soda ash sold.

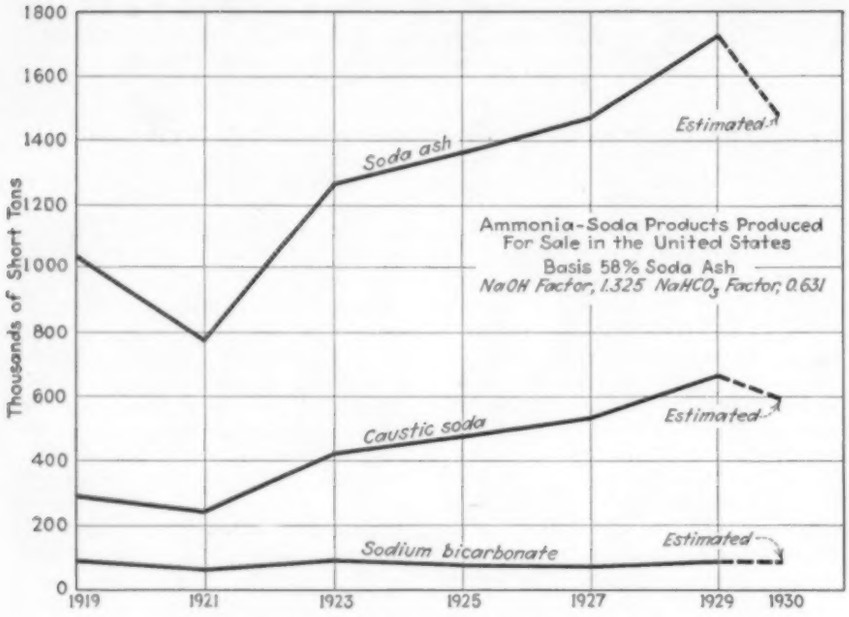
There is no apparent reason why an ammonia soap could not be made. The stability and keeping qualities, and the attitude of the household and laundry consumer, are points which would require careful attention and considerable research work before the application of ammonia to soap making could be safely undertaken. The use of alkali in the manufacture of rayon by the viscose process involves the formation of cellulose xanthate and its subsequent decomposition. Here again extensive research would be required to determine whether

Table I—Comparison of Alkali Content and Relative Cost of Alkalis

Product	Alkali Content	Equivalent Na_2O, Per Cent	Market Price, Dollars F.O.B. Works: Per Short Ton of Product	Market Price, Dollars F.O.B. Works: Per Short Ton of Equivalent Na_2O
Lime	98 per cent CaO	108.5	7.30*	6.70
Soda Ash	58 per cent Na_2O	58	18.90†	32.60
Caustic Soda	76 per cent Na_2O	76	49.70†	65.30
Ammonia	100 per cent NH_3	182	108.50‡	59.60
Borax (98–99 per cent)	16 per cent Na_2O + 36 per cent B_2O_3	16 + 32	35.50†	74.00§

*Average price for lime sold for "chemical uses," f.o.b. point of shipment in 1929, as reported by U. S. Bureau of Mines.
†Average value of soda ash (ammonia-soda), caustic soda and borax for sale in 1929, as reported by U. S. Bureau of the Census.
‡Contract price, 1930 f.o.b. works including tank car rental.
§Basis of total alkali content; $222 on basis of Na_2O content alone.





Production for Sale of Ammonia-Soda Products

ammonia could be used for this purpose. It is obvious that a great deal of technical effort is involved in the introduction of ammonia as an alkali. Research work, it is understood, is at present being conducted to determine if ammonia can be used in making paper pulp.

Marked decline in borax prices in recent years has stimulated interest in borax for other types of glass than the borosilicate glasses, which have special heat-resistant properties and special uses, especially as laboratory glassware. From the standpoint of cost at present prices, the total glass-making ingredients in borax (Na_2O and B_2O_3) are more than twice as expensive as the equivalent alkali content of soda ash. Therefore, the substitution of borax for soda ash tends to increase raw material costs. However, the addition of borax to the glass batch in relatively small proportions effects economies in manufacturing costs which tend to offset increased material costs. Addition of borax reduces the time of melting and the amount of heat required, bubbles are eliminated more quickly, and the output of glass per tank per day is increased. Borax also improves brightness and strength of the glass. The only apparent disadvantage is that borax tends to increase corrosion of ordinary tank linings, but this can be overcome through the use of special refractory linings.

Borax in ordinary types of glass, therefore, is primarily justified by the improved quality of the glass made and by improvements in the manufacturing conditions. In using borax, it is recommended that two parts of borax by weight be used to replace one part of soda ash. It is estimated that not over 5 per cent of the soda ash used in glass is likely to be replaced by borax. This means, at the present rate of consumption of soda ash in glass, that a maximum of 30,000 tons of soda ash might be replaced by 60,000 tons of borax. From the standpoint of tonnages involved, this possible substitution is of much greater importance to the borax industry than to the soda ash industry, as the production of borax in 1929 was 92,250 short tons. It is estimated that the present consumption of borax for glass, other than special borosilicate glasses, is 10,000 to 15,000 tons per year.

Table II—Production of Caustic Soda in the United States

(Short Tons)

Year*	Lime-soda	Electrolytic	Total
1921.....	163,044	75,547	238,591
1923.....	314,195	122,424	436,619
1925.....	355,783	141,478	497,261
1927 (revised).....	387,235	186,182	573,417
1929 (revised).....	524,985	233,815	758,800
1930 (estimated)..	440,000	200,000	640,000

*Figures for 1921 to 1929 are from reports of the U. S. Bureau of the Census. Those for electrolytic caustic do not include that made and consumed at wood-pulp mills, estimated at about 30,000 tons in 1927 and 1929.

In certain cases where the greater causticity of caustic soda, as compared with soda ash, is required, as in soap making or the mercerizing of cotton, it becomes a question whether it is more economical to purchase caustic soda or to purchase soda ash and causticize with lime. Each case must be determined on its own merits after consideration of all factors. In general, where the requirements are large and the caustic can be used in fairly dilute solutions, it usually is economical to purchase soda ash and causticize. On the other hand, where solid caustic or solutions of high concentration are required, it usually is more economical to purchase caustic soda, since the alkali producer can do the necessary conversion and concentration cheaper than the small consumer.

The Past Year in Alkalis

Price developments were lacking for the greater part of the year, but, with the approach of the contracting season, selling competition reached one of the most acute stages ever experienced in the industry. This condition continued throughout the final quarter, with reports that soda ash had sold as low as $14 per ton and caustic soda at $44 per ton. Open quotations were purely nominal and forward business was a matter of private negotiation. Reports varied regarding the volume of contract business placed, but a fairly large part of 1931 production was sold ahead, although many large consumers had not covered by the end of the year.

In production the situation was somewhat better and the decrease in output was less than in most branches of the chemical industry. Preliminary census figures now available for 1929 show that operation was close to maximum capacity during that year. Estimates of the distribution of alkalis in 1930 have been prepared by *Chem. & Met.*, and indicate that consumption in 1930 was only 10 to 15 per cent below the peak of 1929.

Further expansion in alkali plant facilities, which became available late in 1929 or during 1930, has augmented productive capacity. Entering 1931, the ammonia-soda plants have a total annual capacity of from 2,700,000 to 3,000,000 short tons of 58 per cent soda ash, the lime-soda caustic plants a yearly capacity of about 550,000 short tons of 76 per cent caustic, and electrolytic plants, of about 320,000 short tons of 76 per cent caustic. Estimated production for sale of ammonia-soda products during 1930 is shown in the chart at the left, together with similar data for previous years. Table II gives caustic soda production by processes since 1921.

✦

1930 Sees Increase in Sulphur Mining

DOMESTIC production of sulphur in 1930 is estimated to have reached a total of about 2,525,000 tons, a gain of about 7 per cent over 1929. This represents 87 per cent of the estimated world total for 1930 of 2,900,000 tons. (All figures are long tons.) Total United States shipments of about 2,030,000 tons compared with 2,437,238 tons in 1929; shipments to domestic consumers of an estimated 1,465,000 tons compared with 1,582,055 tons in 1929; and exports dropped from 855,183 tons in 1929 to about 565,000 tons in 1930. World production increased about 100,000 tons but shipments dropped from 2,800,000 tons in 1929 to about 2,450,000 tons. Both Sicily with 245,000 tons, and Italy with 88,000 tons showed production gains. In the case of pyrites, world production was at about the level of 1928-9, with an estimated production of 7,000,000 tons. United States imports were about 390,000 tons, compared with domestic production approximating 250,000 tons.

Three-Cornered Competitive Battle Centers About Sulphuric Acid

Editorial Staff

ALTHOUGH sulphuric acid is one of the cheapest of heavy chemicals, and the cheapest of all acids, it is nevertheless the center of a three-way competitive situation which bids fair to become even more severely contested as time goes on. As a chemical, sulphuric acid must compete with other materials that offer advantages capable of offsetting its lower price. Simultaneously, various raw materials are competing for the opportunity of supplying the sulphur consumed in acid production. And, finally, as the third phase of the competitive battle, proponents of the several sulphuric acid manufacturing processes are gathering for the fray, hastily collecting ammunition in the way of facts and figures as they come. Here we may expect to find the most bitterly waged competition of the three.

During 1930, production of sulphuric acid was better maintained than most commodities. As estimated by *Chem. & Met.*, this production amounted to 7,625,000 tons on a 50 deg. Bé. basis, a decline of only 8.6 per cent from the all-time peak of 1929. Actual output of a group of plants normally producing about 13 per cent of the total decreased 9.6 per cent. Analysis of the figures given in the accompanying table will show, however, that two consuming factors, fertilizers and petroleum refining, were principally responsible for high showing of the industry, with declines of 2.8 and 5.4 per cent respectively from the 1929 level. Of the smaller consumers, rayon and chemicals declined 3.4 and 7.8 per cent and all others suffered more than the average reduction. Iron and steel consumption of acid was 17.5 per cent below 1929; other metallurgical uses, 17.1 per cent; coal products, 14.4 per cent; textiles, 13.4 per cent; paints and pigments, 11.6 per cent; miscellaneous uses, 10.3 per cent; and explosives, 9.2 per cent.

These decreases in large part appear to have been due to the general depression rather than to displacement of sulphuric acid by other materials. In some few instances, competitive factors were responsible for part of the decrease, but these are as yet relatively unimportant in their effect on the total. Some may be expected to become more important, and other factors as yet only conjectured are impending competitors.

Among the most powerful competing influences are those that will be encountered in fertilizers and fertilizer raw materials. As a fertilizer raw material of present importance and even greater future consequence, nitric acid is a remarkable example of this tendency. Where a few years ago all of this material was made by potting Chile nitrate with sulphuric acid, now the bulk is produced by the oxidation of ammonia. Even in chamber sulphuric acid plants themselves, direct addition of nitric acid and the oxidation of ammonia have displaced niter potting as sources of nitrogen oxides. And while nitric acid production has almost eliminated sulphuric acid from its own raw material requirements, it is simultaneously bidding for sulphuric acid markets in other fields. An interesting possibility is the use of nitric acid instead of sulphuric in the treatment of phosphate rock. Extensive use of any of the three variations of the Dorr-Liljenroth process, one form of which eliminates sulphuric acid entirely, would make very substantial cuts in H_2SO_4.

As a component of fertilizer raw materials, sulphuric acid suffers a severe disadvantage. It serves only as a carrier or means of making some other material available, and has itself little or no fertilizer value. Nitric acid, on the other hand, answers the demand for nitrate in fertilizer and at the same time serves to increase the availability of other materials. Phosphoric acid has the same advantage, and it has been used for the production of the so-called triple superphosphate from phosphate rock. When the acid used is itself a fertilizer material, instead of being only a carrier, as is sulphuric acid, demands for concentrated and complete fertilizers are often more easily met.

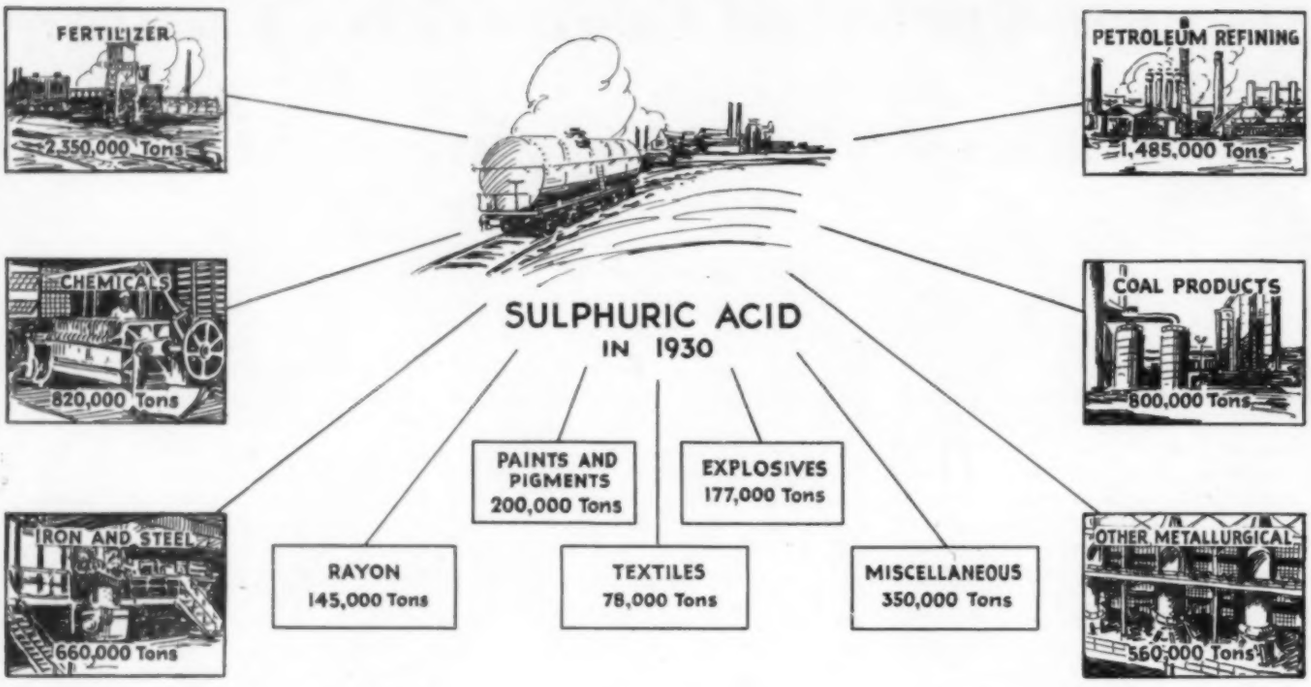
This trend toward concentrated fertilizer has still another angle. Although scarcely manifest as yet, there is an increasing tendency for gas and by-product coke plants to dispose of their ammonia as either the aqua or anhydrous product, rather than as sulphate. Still another possible loss to sulphuric acid lies in the various substitute methods that have been suggested for providing sulphate radical. The Merseburg process employed by the German I. G. in making ammonium sulphate is a case in point. This process, as does the Dorr-Liljenroth, makes use of gypsum plus CO_2 instead of sulphuric acid. Phosphoric acid may also find use in fixing ammonia, for its cost as an ammonia carrier probably can be entirely offset by its fertilizer value, enabling the producer to save the entire cost of the sulphuric acid.

In the production of phosphoric acid, as in the case of nitric, sulphuric acid has struck competition. Apparently the wet process is still supreme for the making of phosphoric acid of fertilizer grade and strength, but for other purposes the thermal processes suffer little or no competition from the wet method. Proponents of both the electric- and blast-furnace processes are pushing costs constantly lower, and it is not inconceivable that one system or the other may eventually displace the wet process entirely, especially where strong phosphoric acid is needed.

On the other hand, there is another side to the picture which shows sulphuric acid not without recourse in fertilizers. One consideration, naturally, is its low cost; another, the fact that it is in, and its competitors, on the whole, are outside looking in. Even the niter potting method for nitric acid has its surprises. One consequence of the rise of ammonia oxidation has been the development of a shortage of niter cake, which now brings as much as

Estimated Distribution of 50° Bé. Sulphuric Acid Consumed in the United States

Consuming Industries	1928 Short Tons	1929 (Revised) Short Tons	1930 Short Tons
Fertilizers	2,300,000	2,418,000	2,350,000
Petroleum refining	1,350,000	1,570,000	1,485,000
Chemicals	745,000	890,000	820,000
Coal products	740,000	935,000	800,000
Iron and steel	670,000	800,000	660,000
Other metallurgical	570,000	675,000	560,000
Paints and pigments	205,000	225,000	200,000
Explosives	170,000	195,000	177,000
Rayon	105,000	150,000	145,000
Textiles	78,000	90,000	78,000
Miscellaneous	292,000	390,000	350,000
Total	7,225,000	8,338,000	7,625,000



$12-$16 at the plant, and even higher. Only recently, it has been reported that one plant is preparing to install nitric acid retorts to make the acid and niter cake from $NaNO_3$.

Another factor in the fertilizer situation, favorable to sulphuric acid, is the demand for ammoniated superphosphate. This recent development, if its spread should continue as is now indicated, will permit sulphuric acid to retain at least a substantial hold on the phosphate business. But the most important consideration, according to many authorities, is that the fertilizer industry is not now, and may not be for years to come, in a position to scrap existing plants and assume additional heavy capital investments. These factors make it unlikely that sulphuric acid will lose ground in fertilizers at any very rapid rate.

Possible loss of sulphuric acid markets is more imminent in the petroleum industry. Traditional practice in refining gasoline has been to reduce sulphur content to 0.1 per cent by an acid treatment which also removes gum-forming compounds. It is estimated that this procedure costs the industry, over the expense of adequate refining, an excess of $50,000,000 per year in loss of product, reduction in anti-knock properties, and acid. Recent work indicates that such stringent reduction in sulphur is neither necessary nor desirable, since much higher sulphur content appears to be without damaging effect on modern motors. Specifications, therefore, are tending toward more liberal requirements, and the possible decrease in acid consumption is large. Should hydrogenation make widespread gains, the probable loss is even greater, for this process eliminates the sulphur as H_2S and makes acid necessary only for the removal of gum-forming constituents.

In other fields, sulphuric acid has met reverses which, taken in the aggregate, may yet become large. Among chemicals acetic acid is a good example. Here direct processes, which remove the acid from pyroligneous liquor without the intermediate calcium acetate step, have eliminated the use of sulphuric acid by a large part of the industry. Synthetic processes have further reduced H_2SO_4 consumption. Hydrochloric acid is another example. The old salt and sulphuric method gave way to the salt and niter cake process, which has in turn yielded to the production of HCl as a byproduct of organic synthesis, and by the combustion of chlorine and hydrogen.

Iron, steel, and other metallurgical operations have consumed great quantities of sulphuric acid, principally for pickling. The rise in recent years of inhibitors and electrochemical methods which require little acid, has already cut into the market for H_2SO_4, and may be expected to do so to an even greater extent.

There are many other possible and probable points of attack, but space is not available for their discussion. As a basic and extremely well-known material, sulphuric acid may expect to become with increasing frequency the butt of cost-reducing programs. Low price and ease of manufacture are powerful considerations, however, and it is improbable that any wholesale displacement of the acid will occur.

Competition of Raw Materials

Three sources of sulphur at present compete as sulphuric acid raw materials. These are brimstone, pyrites, and byproduct SO_2 from smelter gases. Spent gas-house oxide, still used in Europe, was at one time a competitor, but appears now to be of no importance as a sulphur material in the United States. Of the three active sources, sulphur is by far the largest factor in this country, accounting for about 5,195,000 tons of acid (50 deg. Bé. basis) in 1930. Pyrites was second, with an estimated 1,680,000 tons; and byproduct gases third, with 750,000 tons. This corresponds to 1,071,100 short tons of sulphur and 716,800 short tons of pyrites. All of the sulphur was domestic production, while it is estimated that 61 per cent of the pyrites was imported. Pyrites is a heavy commodity of only about 48 per cent available sulphur content, and its low price, while attractive in comparison with brimstone, still does not permit its competing with the latter except along the Eastern seaboard and where hauls are short. The lesser purification needed by brimstone gases is an important factor in the general preference for brimstone. Capital investment for a brimstone plant ordinarily is smaller because of simpler burning and purification equipment. Difficulty in disposing of the pyrites cinder is still another consideration which makes pyrites burning impracticable in many cases.

This competition appears fairly simple and clear-cut. It may not remain so. Estimates place the present recovery of byproduct metallurgical SO_2 at from 10 to 40 per cent of the total of that economically suitable for H_2SO_4 production. Legislation, actual or impending, may be expected to demand increasing recovery as time goes on. Although much of the smelting is now carried on in scantily populated districts, shifting of population or the proximity of agricultural and grazing lands may give rise to sentiment which cannot be disregarded, while unrecovered gases now being discharged in more thickly populated regions will in

all likelihood evoke legislation. One authority anticipates that the Middle West, the Tennessee region and the Idaho-Montana district are the future producers of cheap sulphuric acid and that they will doubtless become important fertilizer centers. Another believes that the Southwest should be added to this list.

Stack gases from power plants constitute another target for legislators. Work now being carried out is looking toward the recovery of SO_2 from such gases. Perhaps the recovery of pyrites from powdered coal before combustion, using a flotation process, may prove the answer to this pollution problem. In any event, the possible recovery of sulphuric acid is large, although the threat is not immediate.

Sulphur recovered from the various liquid purification processes, now finding a place in the byproduct coke industry and in manufactured gas plants, is another possibility. At present the material so obtained is neither suitable for acid manufacture nor considerable in quantity, but it may be a potential competitor of mined sulphur.

Lastly, petroleum hydrogenation, already mentioned as a possible reducer of acid demand, may actually turn the tables and make the refining industry a large H_2SO_4 producer with acid to sell. Should hydrogenation become general, it is inconceivable that refineries would be permitted to discharge enormous quantities of hydrogen sulphide into the atmosphere. Based on petroleum consumption at the 1929 rate, 173,000,000 short tons, and assuming an average value of ½ per cent sulphur, there would become available from this source approximately 865,000 tons of sulphur, equivalent to 4,200,000 tons of 50 deg. acid, or slightly more than half the entire 1930 sulphuric acid production from all sources.

Competition of Processes

The direction in which sulphuric acid manufacture is traveling is not entirely clear, although contact processes very evidently are gaining. During 1930, new construction was limited to contact plants and added an annual capacity of 133,000 tons of 100 per cent acid to the previous total. Production by contact plants in 1930 is estimated to have been slightly over 39 per cent of the total, although it is improbable that such plants represent more than about 30 per cent of installed capacity. This compares with contact production of 30.2 per cent in 1927.

From the earliest days of alchemy until late in the last century, the chamber sulphuric acid process, eked out with the distillation of ferric and other sulphates, supplied the entire H_2SO_4 demand. In the 90's, interest in the catalysis of SO_2 was rife, and contact plants were first built at about the beginning of the present century. Iron oxide and platinum on asbestos and magnesium sulphate carriers were the catalysts used. Iron oxide, giving very low conversion, soon dropped out, leaving only the platinum catalysts. In May, 1926, Silica Gel was first used commercially as a platinum carrier in a Belgian plant and was found to offer certain advantages over the earlier materials. This installation was followed by four others in Europe, England, and Africa; and by seven units totaling 175 tons of daily 100 per cent capacity at the Davison Chemical Company's plant in Baltimore. Again in 1926, the first commercially successful vanadium catalysts were introduced. The catalytic effect of vanadium compounds had been recognized for about 40 years, but it had not previously been possible to find compounds which would give conversions comparable to platinum.

Meanwhile, for the last 30 years there has been much interest in improved chamber systems. Many devices have been tried, including towers between chambers, systems consisting entirely of towers, special shapes of chambers, flue systems, and special mixing equipment, most of which have since been abandoned. In Europe, tower systems are still much used, although they have made no headway in the United States. Europe also makes use of the Schmiedel box and the Gaillard system to intensify operation by improving contact of acid and gases. Many plants in Europe are of the Mills-Packard design, employing special chambers and external water-cooling. In the United States efforts were directed with considerable success toward the intensive operation of ordinary chambers. Many plants now run satisfactorily on as little as 8 cu.ft. of space per pound of sulphur per day. Modified plants, such as the Pratt, exhibit even better space rates. A number of Mills-Packard plants have been built and these have operated on as little as 3.25 cu.ft. per daily pound of sulphur. Other intensive systems have not as yet made progress in the United States.

In the face of a belief in many quarters that the sulphuric acid industry now has so much excess capacity that further building is improbable for several years, it may seem idle to speculate on the course of future building. Two trends, however, make this view untenable. Byproduct SO_2 (and perhaps H_2S) recovery is going to account for a great deal of building sooner or later; normal replacement for a small amount; and the erection of plants by users who have previously been purchasers, of considerable. The magnitude of this new building is highly speculative, although it seems unlikely that an annual rate less than that of the past year will prevail.

It is now generally conceded that the investment cost of comparable straight chamber and contact plants is substantially equal, or slightly in favor of the latter. An unbiased authority states that production cost also, except in the case of a pyrites plant producing 50 deg. acid on the Eastern seaboard, is actually less for contact plants. In other words, for plants producing acid stronger than 50 deg. from either pyrites or brimstone, modern contact processes give lower total costs. In the light of this improvement and in the superior flexibility of contact plants as regards strength of acid produced, weight seems to be given to the belief held by many acid men that the chamber process, as new construction, has outlived its usefulness. Whether such processes as the Gaillard can compete successfully with contact plants in the United States as they are doing in Europe, remains to be seen.

Competition of Catalysts

Granting then a distinct possibility that contact plants will represent the bulk of new construction, the question of catalysts comes to the fore. Although laboratory tests can be advanced as a claim for superiority of either type, actual plant use has demonstrated that platinum and vanadium catalysts give approximately equal conversion. Platinum catalysts will operate at a somewhat lower temperature and will convert more SO_2 per pound of catalyst, but this is readily equalized by increasing the quantity of vanadium mass used. Examination of a large number of plants has shown the average over-all conversion efficiency for both types under normal plant loading to be 95.4 per cent in the range from 15 per cent below to 10 per cent above rated capacity. On the basis of catalyst cost, the two are again comparable at present platinum prices of about $36 per troy ounce. If anything, the difference is in favor of platinum, because of its scrap value.

Of the platinum plants in the United States, only Davison is at present known to be using Silica Gel carrier. Several plants are using magnesium sulphate, including two of the largest producers, but the majority are believed to be employing platinized asbestos. With the latter, the requirement ranges from 5 to an average of 8 oz. of platinum per ton of daily 100 per cent capacity. On the average, platinized asbestos catalyst requires regeneration about every seven years. In calculating platinum costs, the following values per ton of daily 100 per cent capacity apply: Preparation and asbestos base, $85-$100; regeneration, $50; platinum loss per year, 1 per cent. Based on a period of 15 years, with credit for recovered platinum at the end of the period, cost of catalyst per year per daily ton of 100 per cent capacity becomes $22.87. The oldest plant using vanadium catalyst has now operated for about five years without decrease in efficiency. Consequently, no one can say how long vanadium can be used efficiently. A 15-year period may be much too short,

since screening to remove accumulated dust satisfactorily revives vanadium catalyst which has become choked. If we assume, however, that vanadium is efficient only for 15 years, then cost per year becomes somewhat higher than platinum. This, the makers justify on the basis of lower total investment and a belief in the superiority of vanadium.

As is generally conceded, the older platinum catalysts, being subject to poisoning by chlorides and arsenic, require more purification equipment than vanadium plants, and somewhat more careful operation, especially with pyrites and smelter gases. It is claimed for platinized Silica Gel catalyst that it is not affected by arsenic, and that reconditioning, in the case of poisoning, may be effected by blowing hot air at 800 deg. F. through the converter. Total cost of this catalyst is approximately $420 per ton of daily 100 per cent capacity, but its salvage value is fairly low, since its platinum content is only a third of the usual requirement, about 2.5 troy ounces. Guaranteed conversion is 94 per cent, although experience since April, 1928, with the Silica Gel units at the Davison plant has shown a figure of 96 per cent when throughput does not exceed 0.32 cu.ft. per minute per pound of mass.

It does not appear that either vanadium or one of the three platinum catalysts has yet demonstrated conclusive superiority over its competitors. Doubtless the results of the next few years will indicate more clearly which way the wind of user favor is blowing.

Complex Situation Impending in Acetic Acid Manufacture

By F. J. Curtis

Director of Development
Merrimac Chemical Company
Boston, Mass.

Wood distillation, thanks to the new direct acetic acid processes, has renewed its lease on life. But several other processes are important potential competitors. Wood, lime and coke, molasses, natural gas, petroleum, and waste cellulose are all raw materials either now in use or probable for the future.

ACCELERATION of the change in our manner of producing goods and of living, the scientific revolution which has brought untold benefits since its beginning 30 to 35 years ago, has also had its penalties. One of the most outstanding of these is technical instability. As a result we hear the term "technological unemployment" in all of the current discussions of the business depression and its consequences. This is a term which is not only applicable to labor, its usual sense, but also to capital already invested in processes, the stability of which is hit both by changes in use and in methods of manufacture.

One example of an industry which is now going through this technological adjustment is the manufacture of acetic acid, a product which grew slowly over the years, and then, as has been a characteristic of the scientific revolution, experienced a great change in the rate of growth. Taking 1923 as the base, it becomes evident, from the tabulation below, that the more recent development of acetic acid production has progressed by leaps and bounds:

	Index		Index
1923	100	1928	193
1925	115	1929	213
1927	161	1930 (based on first half) ...	240

Any such rate of growth is certain to disturb the original sources and methods of manufacture. The greater market tempts research and the development of new and still cheaper methods of production.

Until 15 years ago the chief use of acetic acid was in textiles, where it was employed, among other things, as an adjunct in dyeing. Edible vinegar is also a consuming industry, although in the United States it has been restricted to the fermented product and so has not come into relation with the main manufacturing methods. The manufacture of acetates and a host of miscellaneous uses at that time made up the balance. Following the war the introduction of the nitrocellulose lacquers brought about a great increase in the production of the organic acetates. Ethyl acetate, from 1923 to 1929, increased from 25,888,000 to 73,895,000 lb. Butyl acetate in the same period went from 1,816,000 to 38,780,000 lb. and amyl acetate from 1922 to 1928 grew from 1,692,000 to 4,290,000 lb.

The introduction of cellulose acetate rayon and its remarkable growth in the last few years brought about additional consumption of acetic acid, both as such and in the form of acetic anhydride. In comparison with 4,700 tons of acid in 1927, it is estimated that 11,000 tons was used in 1929, with an equal amount of anhydride.

Rapid growth of home motion-picture photography and the accidents which have taken place with nitrocellulose film have given considerable impetus to the manufacture of cellulose acetate safety film. Such new uses have all resulted in a rapid increase in demand and in the construction and projection of new manufacturing centers.

So far there has arisen no serious threat against the dominance of organic acetates as solvents. Glycol ethers are being used, but even in this case there is a tendency to prefer their acetates. Other esters of cellulose have been proposed, such as benzyl cellulose, butyrate, and proprionate. The butyrate has been developed in France, but no extensive application seems as yet to have resulted. Work is being pushed on methods of manufacturing the proprionate, but the development is too recent to warrant estimation of its value. Certain synthetic resins are being developed which it is expected may displace a part of the cellulose ester. The glycerine-phthalic anhydride resins are said to be used along these lines. Undoubtedly further research will develop substances which may cut down the quantity of ester used, but will not completely substitute for it.

In the textile industry there was a tendency a short while ago to displace acetic acid with formic acid for certain dyeing operations. The pH value of dilute solutions of formic acid is intermediate between that of sulphuric and acetic acids, so that formic has a better exhausting efficiency than acetic, without the danger of irregular dyeing sometimes found with sulphuric. The recent lowering of the price of acetic acid probably will put a stop to this tendency for the time being. Thus, while one finds inter-commodity competition in the acetic acid field, it seems as yet to be less serious than in other cases.

In inter-process competition, however, the situation is quite different. Until 1928 all of the acetic acid manufactured in the United States was a byproduct of the distillation of wood. This industry has four chief products: methanol, acetate of lime, wood tar oils, and charcoal. The synthetic production of methanol in a large way, along with ammonia or alcohols, has resulted in an oversupply of this product and a consequent fall in price. Wood charcoal as a fuel has a tendency to be displaced by natural gas, petroleum, and coal.

Acetate of lime, therefore, is called upon to bear an increasing share of the charges of wood distillation and, at the

same time, has dropped during the past six months from $4.50 per 100 lb. to $2. The position, then, of the wood distillation industry would have been rendered precarious by the economic changes and scientific advances of the past few years were it not that in this industry also, scientific development has been taking place. The process of converting pyroligneous acids to calcium acetate, and then in turn to acetic acid by means of sulphuric acid, is obviously too long drawn out to stand modern competition.

This process has been cut short by a number of so-called direct acetic acid processes. These processes may be divided into two types: (1) liquid phase, and (2) vapor phase. The first type is represented by the method which uses ether as a solvent. The pyroligneous acid, after a primary distillation, is extracted with ether and the ether and water layers are separated. The ether is then distilled off, leaving the acetic acid behind. There have been a number of vapor phase extraction methods brought out, the most important of which seem to be the Suida process, using wood tar oils from the distillation itself; the ethyl acetate process; and one developed abroad using a mixture of ethyl and amyl acetates. Plants using these processes are in practical production in the United States and it is believed by those in charge of the operation that by this shortcut method the wood distillation industry will still be able to compete with the synthetic. The present era of low prices will test out this claim.

Hydrolysis of wood by both acid and alkaline methods has received more attention abroad than in the United States. It is reported that a process has been developed in Germany whereby wood is digested much as in the pulp industry, rather than being subjected to pyrolytic decomposition. The result is that increased yields of acetic acid are obtained and the primary product is much purer and more easily refined. The process is not yet far from the laboratory and it is too early to appraise its importance.

THE FUTURE of wood distillation lies along such lines of more scientific processing, development of special uses and special grades of wood tar oils and charcoal, and in the use of waste wood in connection with lumbering and woodworking plants. The industry is going through a period of painful adjustment at the present time, but there is no reason to doubt that the more progressive plants will survive.

Next to wood distillation, the class of processes which has been most in the public eye includes those which depend on acetylene. In general practice these methods have not differed materially in the steps subsequent to the production of CH_4. Ordinarily, acetylene is converted to acetaldehyde by means of oxygen or air, with the help of a mercury sulphate catalyst and sulphuric acid. The acetaldehyde is then oxidized to acetic acid. Many variations of these steps have been proposed, but that given above seems to be generally used. The processes differ widely among themselves, however, in the method of obtaining the original acetylene. The most outstanding process and the only one as yet in commercial production in the United States uses calcium carbide, the reaction of which with water is the ordinary method of making acetylene.

Production of acetic acid in a carbide plant is particularly attractive, because by this means any off-grade carbide can be utilized. The raw materials are lime and coke, both generally available, but the necessity of cheap power for the electric furnace defines its location. The process is particularly attractive to power companies with waste power and will continue so until the growth of a general industrial load forces the cheaper chemical power further away from the market. Calcium carbide produces a strong and relatively pure gas and the two steps of conversion are well worked out. This is now the only industrial competitor of wood acetate in this country.

Conversion of methane to acetylene has been the subject of research for some time. It has been stimulated by the enormous supply of natural gas now being made available by pipe lines to industrial centers. A great deal of original research work has been done in Germany by Fischer and Peters and others. Further scientific work was carried out by Frolich at the Massachusetts Institute of Technology. In Germany the I.G. and some of the coal companies are said to have developed this method. Processes fall into two classes: (1) Those depending on incomplete combustion; and (2) those in which the methane is subjected to high temperature, with or without catalyst.

The methane process as a source of acetylene is still in the experimental stage, one of the difficulties being to produce a single product. It is favored by extremely low raw material cost in this country, but one of the outstanding difficulties seems to be high power cost. If this can be solved it is possible that we will have a method of manufacturing acetylene which may well compete with that from any other source.

In Italy, experimental work has been going on for some time with the electrodecomposition of petroleum oils, whereby it is said that acetylene is produced. As far as is known, no acetic acid is being made by this process, but it may be a potential source.

Production of acetic acid by catalytic methods from alcohol, while not depending exactly on acetylene, nevertheless falls close to this classification, because the primary product is acetaldehyde, which is then converted to acetic acid in the usual manner. A plant has been erected in England for the production of acetic acid by this method, and a process which, however, has not as yet reached commercial production, has also been worked out in the United States. With molasses decreasing in price and methanol displacing ethyl alcohol, this process for the manufacture of acetic acid may become interesting to manufacturers of ethyl alcohol.

High-pressure methods, now so much in evidence in the chemical engineering field, have been applied to the conversion of methanol directly to acetic acid by the addition of carbon monoxide. This is widely different from any of the other synthetic methods. It uses a material the production of which is increasing and which apparently will continue to increase as synthetic ammonia plants grow. Methanol is dropping in price and has an assured supply. The process also goes in one step to acetic acid, with the elimination of difficulties always inherent in multi-stage methods.

ACETIC acid for vinegar has been produced by fermentation from time immemorial. At least one company in the United States, however, is using this method to obtain a weak acetic acid solution which is applicable to the manufacture of esters. The most recent development in fermentation has been the Langwell process for the fermentation of cellulose. It has been reported that the company exploiting this will construct an acetic acid plant to use this process and that it has projected several additional units. As raw material, waste cellulose from both their present fermentation and from outside sources will be used. Certainly, such a method will not lack for bases. Most fermentation processes have been wrecked by the production of a variety of materials, at low concentration. It has not heretofore been possible to obtain bacteria which could work in a high concentration of their own product. If these problems should be solved, further fermentation industries may be expected.

This brief survey has shown an astonishing range of raw materials now being used or proposed for the manufacture of acetic acid. We have wood, lime and coke, molasses, natural gas, petroleum, and waste cellulose. All of these are produced on a relatively large scale, some of them, such as wood, molasses, and waste cellulose, being by-products and therefore having normally no value except that to the user. With others, acetic acid must compete for its raw material with other applications. At the same time natural gas and petroleum used for acetic acid should have a higher value than for fuel. An equally wide range is seen in the conversion methods. Pyrolytic distillation, power consumption, organic catalytic oxidation, high-pressure synthesis, and fermentation are all being proposed for the manufacture of this product. The acetic acid industry has ahead of it a considerable period of experimentation, due to the richness of the possibilities developed. It would appear improbable that any one process will suit all conditions.

Natural, Refinery, and Water Gas As Hydrogen Sources

An Economic Study

EVOLUTION is still in progress in the production of hydrogen. Water gas no longer stands unchallenged in this country as the starting point in the synthesis of ammonia or in the hydrogenation of fuel oils. Plants are now under construction in which both natural gas and petroleum refinery gas are used also as sources of hydrogen.

Published data on actual production costs are extremely scant. Operators are naturally reluctant to disclose the exact details of their processes, some of which are scarcely beyond the experimental stage. It is possible, however, to make very approximate estimates of the costs of such procedures as have already been described by their advocates. These estimates have been prepared primarily to illustrate one phase of the operation today of interprocess competition. The methods selected for analysis have been chosen only as typical of the art in general, and no attempt has been made to review exhaustively all hydrogen processes either now in operation or under development.

Three representative methods of producing hydrogen are considered:

1. From water gas (blue gas) in the present conventional manner (Atmospheric Nitrogen Corporation and Du Pont Ammonia Corporation for the synthesis of ammonia).

2. From natural gas or refinery gas by reaction with steam (Standard Oil Company of New Jersey for the hydrogenation of oil and Shell Oil Company for the synthesis of ammonia).

3. From natural gas or refinery gas by cracking without steam and with simultaneous recovery of carbon black (Thermatomic Carbon Company and Natural Gas Hydrogen Corporation).

The production of hydrogen by the electrolysis of water is not included in the present analysis. The special conditions under which electrolytic hydrogen can compete with hydrogen from other sources have already been discussed in an earlier article.* Nor has the production of hydrogen from byproduct sources, such as carbon monoxide from electric furnaces, been considered, since cost estimates for these processes would apply only to specific plants under highly specialized conditions. Coke-oven gas has not found favor in this country as a source of hydrogen. While it has been the practice of certain Continental operators (e.g., the Mont Cenis process) to react coke-oven gas with steam in contact with hot checker brick, no American operator is known to have followed this procedure. The Du Pont Ammonia Corporation at Belle, W. Va., is understood to be burning under its boilers the byproduct gas from its coke ovens, which were completed during the past summer.

Of the three processes enumerated above for discussion, the water-gas method has been in use for many years. Blue gas, or a mixture of blue and blast gases (or producer gas), is reacted with steam in the presence of a catalyst to convert the carbon monoxide into carbon dioxide and a further yield of hydrogen. The carbon dioxide thus produced is removed by solution in water under pressure.

In the second method, natural gas or refinery gas is reacted with steam in two stages. In the first-stage reaction, which is highly endothermic and which takes place at a temperature of 1,500 deg. F. or higher, the bulk of the hydrocarbons is converted into carbon monoxide and hydrogen. The second-stage reaction is similar to that described in the treatment of blue gas. The heat requirement is negligible. The temperature is about 1,300 deg. F., a catalyst is employed, and the carbon monoxide is converted largely into carbon dioxide and more hydrogen.

The first-stage steam reaction may be either intermittent or continuous. Past practice has adopted an intermittent cycle, in which the hydrocarbon gas is circulated through checker brick periodically heated by the combustion of another portion of the gas. It is understood that some process resembling this procedure in principle will be employed by the Shell Oil Company in its synthetic ammonia plant now under construction in California.

The Standard Oil Company of New Jersey, on the other hand, has developed a continuous first-stage steam treatment. Externally heated alloy steel tubes are employed, and a catalyst is used to permit a lower operating temperature. Large-scale hydrogenation plants embodying this procedure are now under construction. Refinery gas will be used at Bayway, N. J., and natural gas at Baton Rouge, La., and Houston, Texas.

The direct cracking of natural or refinery gas has not yet been selected as a process of manufacturing hydrogen by any company now active in ammonia synthesis or oil hydrogenation. At Sterlington, La., natural gas is being converted by the Thermatomic Carbon Company into hydrogen of a high concentration by passage over heated checker brick in an intermittent cycle. To date, however, the operation has been carried out only for the production of carbon black.

At Louisville, Ky., on the other hand, the cracking of natural gas is accomplished by the Natural Gas Hydrogen Corporation in an ordinary water-gas generator. A bed of fuel is blasted in the conventional blue-gas procedure, but during the "run" portion of the cycle, natural gas (or refinery gas) is circulated instead of steam. Byproduct carbon black is recovered, but its sale apparently is not so essential to the commercial success of the operation, as in the case of the process just described.

Nearly all of the above processes are subject to numerous ramifications. They are vitally affected by the use to which the hydrogen is to be put; i.e., whether for ammonia synthesis or for the hydrogenation of fuel oils. For the former purpose hydrogen made from blue gas, for example, can be somewhat cheapened and the production capacity of the apparatus increased by producing it in admixture with nitrogen. This result is accomplished by adding to the blue gas a certain percentage of blast gas

Table I—Analyses of Gases in Hydrogen Production

	CO_2	CO	H_2	CH_4	C_2H_6	N_2	Cu.Ft. per M. C. F. of Original Gas
From Water Gas							
Low Nitrogen							
Blue Gas	7.0	39.0	49.0	1.0	...	4.0	1,000
After Steam Reaction	31.3	2.5	62.9	0.4	...	2.9	1,375
After CO_2 Absorption	0.6	3.3	91.6	0.6	...	3.9	895
High Nitrogen							
Blue and Blast Gases*	7.5	33.5	36.1	0.7	...	22.2	1,465
After Steam Reaction	29.0	2.3	51.6	0.3	...	16.8	1,930
After CO_2 Absorption	0.8	3.1	71.9	0.4	...	23.8	1,300
By Steam Reaction With Natural Gas							
Natural Gas	....	....	....	90.0	3.0	7.0	1,000
After 1st Steam Reaction	10.0	11.9	74.5	2.0	...	1.6	3,675
After 2nd Steam Reaction	18.4	1.4	77.0	1.8	...	1.4	4,080
After CO_2 Absorption	0.7	1.8	93.3	2.3	...	1.9	3,460
By Cracking Natural Gas							
Natural Gas	....	....	....	90.0	3.0	7.0	1,000
Cracked Natural Gas	....	2.0	91.0	4.0	...	3.0	2,000

*Estimated on basis of adding last ½ minute of blast gases.

*Paul McMichael, *Chem. & Met. Eng.*, August, 1930, pages 484-7.

Table II—Starting Materials and Byproducts

Per M.C.F. of 100 per Cent Hydrogen Produced

	Coke Lb.	Natural Gas Cu.Ft.	Carbon Black Lb.
From Blue Gas			
Low Nitrogen	40	...	...
High Nitrogen	31	...	...
By Steam Reaction With Natural Gas	...	310	...
By Cracking Natural Gas	13	550	3.3

or producer gas prior to purification.

When oil hydrogenation is the objective, on the other hand, nitrogen in any considerable quantity is undesirable, and this procedure cannot be adopted. In general, however, hydrogen for oil hydrogenation is cheaper than hydrogen for ammonia synthesis. This is due chiefly to the necessity in the latter operation of removing from the hydrogen the last traces of carbon monoxide, which acts as a poison to most ammonia catalysts.

In the hydrogen processes involving the conversion, by steam reaction, of carbon monoxide to carbon dioxide and hydrogen, some carbon monoxide always survives this treatment. The quantity of surviving carbon monoxide is, within limits, under control, and depends upon the concentration of steam employed. Its removal is a cumbersome operation. In some plants it is washed out in a solution of copper-ammonium salts. In another plant, the CO-containing gas mixture is passed through a converter at high temperature and pressure over catalysts that promote the union of the carbon monoxide with hydrogen to form either methanol or higher alcohols.

In the accompanying estimates the cost of removing the final small percentage of carbon monoxide has not been calculated, since this factor is common in general to all of the processes considered. Relative costs are estimated only in terms of the hydrogen content of the gas mixtures produced. Attention is directed to the tabulated analyses of these mixtures, in so far as the content of carbon monoxide, carbon dioxide, or methane may be deterrents to the commercial application of these various gases.

Three specific hydrogen processes, representative of the three types outlined above, have been made the subject of detailed calculations:

1. From (A) blue gas and (B) a mixture of blue and blast gases.

2. From natural gas by continuous reaction with steam over a catalyst in externally heated metal tubes.

3. From natural gas by direct cracking in water-gas generators, (A) without and (B) with byproduct carbon black credit.

Table I gives the analysis of gases produced in the successive stages of the three typical processes, together with the volumetric relationships involved.

Table II shows the relationship between the quantities of starting materials and byproducts per M.C.F. of hydrogen produced, according to the assumptions employed in making these calculations.

Table III summarizes the relative plant costs, per M.C.F. of 100 per cent hydrogen at atmospheric pressure, estimated by the relationships in Table I and II by the following assumed unit costs:

1. In operation of processes employing water-gas generators (blue gas production and natural gas cracking), labor, maintenance, depreciation and other fixed charges, and all miscellaneous costs, except generator fuel (coke) and natural gas, to be 8 cents per M.C.F. of gas mixture produced (blue gas or cracked natural gas).

2. Cost of reaction with steam (CO to CO_2) and absorption of CO_2 in water under pressure to be 24 cents per M.C.F. of CO so treated; this charge to include steam, fixed charges, and all operating costs. Power involved in compressing gas not included, other than that strictly chargeable to purification.

3. Cost of first-stage reaction of natural gas with steam in externally heated tubes (CH_4 to H_2 and CO) to be 20 cents per M.C.F. of natural gas so treated; this charge to include steam, fixed charges, and all operating costs except that of the natural gas actually reacted with steam (cost of heating gas included at 15 cents per million B.t.u.).

Table III will be found largely self-explanatory. The production of hydrogen from water-gas is well established and involves few speculative elements. According to the accompanying figures, however, hydrogen from natural gas (or refinery gas) by either of the two other methods promises considerable economy. Large-scale tests of these processes will be awaited with interest.

In the direct reaction of natural gas with steam, tubes are used in which the metal is subjected to very drastic conditions of both temperature and pressure. Excessive maintenance costs seem to be the greatest hazard.

While this technical limitation is absent from the cracking process, on the other hand, this latter procedure requires a satisfactory byproduct revenue to show to best advantage. The carbon black recovered is somewhat inferior to "channel black," and apparently the volume of hydrogen which can most economically be produced is limited to the size of the market which can be found for a black of these properties.

Table III—Summarized Comparison of Hydrogen Costs*

(Cents per M.C.F. of 100 Per Cent Hydrogen)

	With Coke, per Ton @ $3			With Coke, per Ton @ $6		
Natural Gas, Cents per M. C. F.	5	15	25	5	15	25
From Water Gas						
Low Nitrogen Content	27.4	27.4	27.4	33.3	33.3	33.3
High Nitrogen Content	26.5	26.5	26.5	31.8	31.8	31.8
By Steam Reaction With Natural Gas	11.0	14.1	17.2	11.0	14.1	17.2
By Direct Cracking of Natural Gas						
No Carbon Black Credit	13.5	19.0	24.5	15.5	21.0	26.5
With Carbon Black Credit†	5.3	10.8	16.4	7.3	12.8	18.3

*All costs refer to hydrogen at atmospheric pressure and of the quality indicated in Table I.

†Carbon black credit calculated at 3 lb. of black per M.C.F. of cracked natural gas and 2½c. per pound of black (arbitrary credit for illustrative purposes only).

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Synthetic Ammonia Shows Large Increase

EIGHT synthetic ammonia plants now in operation in the United States produced an average of about 450 tons per day of ammonia, according to the best estimates available at this time to the editors of *Chem. & Met.* Furthermore, daily capacity now in production or to become available during 1931 is estimated to be about 825 tons of ammonia. The largest new plant expected to be in operation this year is that of the Shell Chemical Company at Pittsburg, Calif., which when completed will have a capacity of 80 tons per day. Construction of the first unit of 40 tons is now well advanced.

Chem. & Met. Estimates of Synthetic Ammonia Production and Capacity 1929-31

(All figures in short tons of ammonia per day)

Plant	Average Output for 1929	Average Output for 1930	Approximate Daily Capacity 1931
A.N.C., Hopewell, Va.	150	270*	450
A.N.C.,Syracuse, N.Y.	40	40	40
Du Pont, Belle, W. Va.	85	120	215
P.A.C., Seattle, Wash.	3	3	3
R. & H., Niagara Falls	3	3	3
Mathieson, Niagara Falls	12	12	15
Great Western, Pittsburg, Calif.	2	2	2
M.A.C., Midland, Mich.	0	4†	15
Shell, Pittsburg, Cal.	0	0	80
	295	454	823

*Includes ammonia oxidized for $NaNO_3$.

†Operated at 7 tons per day for about one half year but will be up to 15 tons early in 1931.

The expansion of the plant of the Atmospheric Nitrogen Corporation at Hopewell, Va., to a total estimated capacity of 450 tons of ammonia gives it the leading position in this industry. Other producers in the order of their importance include the Du Pont Ammonia Corporation, at Belle, W. Va.; the Syracuse (N. Y.) plant of the Atmospheric Nitrogen Corporation; the Mathieson Alkali Works, at Niagara Falls; the Midland Chemical Company, of Midland, Mich.; the Pacific Ammonia Corporation, at Seattle, Wash.; the Roessler & Hasslacher Chemical Company, at Niagara Falls, N. Y.; and the Great Western Electrochemical Company, of Pittsburg, Calif.

Nitrogen Developments in 1930 Throughout the World

By Chaplin Tyler
Chemical Department
Du Pont Ammonia Corporation
Wilmington, Del.

UNQUESTIONABLY the year 1930 was an eventful and critical period for the nitrogen industry. It was characterized by reorganization and consolidation within the Chilean industry; by the formation of an international cartel controlling the output, prices, and export quotas of 80 per cent of the entire industry; by a renewal of the German Nitrogen Syndicate for a period of either five or seven years; by an increase in inventories that hastened cartelization and price reductions; by a continuance, nevertheless, of plant expansion and new construction; and finally, by the announcement of plans and completion of construction that will, by the end of 1931, make the United States virtually self-contained as respects nitrogen supply for both peace and war needs.

Inter-commodity competition within the nitrogen industry has been more keen than ever, as typified by a few examples: anhydrous ammonia and ammonia liquor are replacing cyanamide and other nitrogen carriers in mixed fertilizer; the relative value of inorganic and organic nitrogen carriers is being re-examined, in view of the very high cost of "organics"; synthetic nitrate of soda is making rapid inroads into the field once dominated by Chilean nitrate of soda; calcium nitrate is favored in citrus culture in California; imports of urea into the United States are becoming significant now that the tariff has been removed; ammonia oxidation continues to displace nitrate of soda in the chamber acid process.

The position of Chile relative to the entire world nitrogen business is indicated by the figures in Table I, reported by Pablo Ramirez, president of the Chilean delegation to the 1930 Nitrogen Conference:

Table I—World Production of Nitrogen

(Metric Tons)

	1913	1918	1929
Chilean nitrate	430,000	444,000	490,000
Syn. and byproduct	317,000	748,000	1,623,000
Total world production	747,000	1,192,000	2,113,000
Per cent of Chilean nitrate	57.6	37.2	23.2

The 1929 figures are deceptive in that Chilean nitrate was overproduced. Actually, the consumption of Chilean nitrate comprised only 18.5 per cent of the total world consumption of nitrogen. Furthermore, stocks of Chilean nitrate in various parts of the world increased to 2,600,000 m. tons by the end of 1929, an uncomfortably large total.

Simultaneously with the decreasing proportion of world nitrogen business obtained by Chile there has been a reduction in price, which as early as 1928 threatened to wipe out profits. Thus, in 1925 the price of nitrate was $48.50 per m. ton f.a.s. Chile, including full export tax, while in 1929 the price had declined to $37.50 per m. ton, a loss of $11 per m. ton, or a total loss of $27,500,000 on 2,500,000 tons of nitrate. Since the *average* costs of the old industry probably were about $25 per m. ton f.a.s. Chile, the break-even price, including tax of $12, was $37 per m. ton. Hence the necessity of rebating part of the tax, and finally of rationalizing the industry.

The second international conference on nitrogen began in Paris on April 25, and was suspended owing to disagreement between the Chilean and European groups as regards quotas of production. It was accepted that the world production capacity was 3,125,000 m. tons of nitrogen, of which Chile had a capacity of 500,000 m. tons; and also that the world consumption was about 1,900,000 m. tons, or 60 per cent of world capacity.

Final negotiations were successful, owing, no doubt, to the ability of the Chilean group to consolidate its position in the form of a quasi-public corporation known as the Compañia Salitrera de Chile ("Cosach").

The essential points of the nitrate law directing the formation and administration of the Cosach can be summarized as follows (See *Chem. & Met.*, August, 1930; pp. 478-9):

1. The Cosach guarantees to the Chilean government an income of $22,500,000 in 1930; $21,500,000 in 1931; $19,200,000 in 1932; and $16,800,000 in 1933.
2. Of the total capital stock of the Cosach, amounting to $375,000,000 the government will hold 50 per cent and the participating producers 50 per cent.
3. After 1933 the government and the industry will participate equally in profits of the Cosach.
4. In exchange for capital stock, the participating producers will transfer all assets and liabilities to the Cosach.
5. The Chilean government will transfer to the Cosach as required, reserves of lands equivalent to 150,000,000 m. tons of nitrate (measured as recoverable by the Guggenheim process).
6. The law concedes the majority of directors votes to the industry, thus insuring free control. However, the government reserves the right to veto such resolutions as appear to be contrary to the national welfare.
7. The Cosach has power to sell bonds in order to meet various needs of the industry.

American Industry Expands

Major developments in the United States nitrogen industry during 1930 were the announcement of a large expansion of the Hopewell works of the Atmospheric Nitrogen Corporation; completion of construction at the Belle works of the Du Pont Ammonia Corporation; announcement of plans by Shell Chemical Company of a projected 80-ton-per-day ammonia plant to be built in California; and completion of the new plant of the Midland Ammonia Company at Midland, Mich. Other developments were the removal of import tariffs on sulphate of ammonia and urea, the greatly extended use of the superphosphate ammoniation process, and the

Table II—Inorganic Nitrogen Statistics for the United States

(Short tons of nitrogen)

Calendar years	1926	1927	1928	1929 (Partly Estimated)	1930 (Estimated)
Production:					
Byproduct	142,000	147,500	164,500	186,000	165,000
Synthetic	12,800	18,000	27,000	100,000	140,000
Total production	154,800	165,500	191,500	286,000	305,000
Imports	203,200	190,300	266,600	242,000	180,000
Supply	358,000	355,800	458,100	528,000	485,000
Exports	45,000	35,900	25,500	48,000	32,000
Apparent consumption	313,000	319,900	432,600	480,000	453,000

increased consumption of synthetic nitrate of soda.

Table II summarizes recent trends in the production, consumption and trade of inorganic nitrogen for the period 1926-1930 inclusive.

That the United States is rapidly attaining nitrogen independence as respects both peace and war needs is demonstrated by the figures of Table III, showing the estimated production capacity of the industry as of the end of 1929, 1930, and 1931.

Table III—Inorganic Nitrogen Production Capacity

(Short Tons of Nitrogen)

	1929	1930	1931
Synthetic ammonia	140,000	175,000	290,000
Byproduct (coke and gas works)	200,000	200,000	200,000
Total capacity	340,000	375,000	490,000
Contract price sulphate ammonia	$44	$41–$44	$35–$38

It should be noted that by the end of 1931 the nitrogen industry could, if forced, meet the probable demand for domestic consumption plus exports. Actually, the industry will not operate at capacity, owing to the dependence of the byproduct industry upon iron and steel production and the impracticability of forcing abrupt reductions in imported nitrogen.

The price reductions accompanying increased capacity are significant. Significant also is the fact that the obsolete Muscle Shoals cyanamide plant, even if modernized, would have a capacity of only 40,000 tons nitrogen per year, less than one-twelfth of the estimated total capacity at the end of 1931.

World Production and Consumption

For the fertilizer year 1929-30, the British Sulphate of Ammonia Federation, Ltd., estimates that the world production of nitrogen increased 65,400 m. tons, or about 3 per cent. While the production in Chile decreased by 26,000 tons, the production in other countries increased by 91,400 tons. The following comments and Tables IV, V, and VI are extracted from the report of the Federation:

The total nitrogen producing capacity in the world at the present time is estimated to be about 2,400,000 tons of nitrogen, exclusive of Chile.

The total consumption increased by 86,640 tons, or 4½ per cent, following on increases for the years 1927-28 and 1928-29 of 25 per cent and 14 per cent respectively.

The tabulated figures are offered as fair estimates of the various forms, but strict accuracy is not claimed for them.

World Nitrogen Cartel—After prolonged and intermittent negotiations, the World Nitrogen Cartel was organized successfully in Paris in August, under the chairmanship of Herr Schmitz of the I.G. The agreement comprises the nitrogen industry of Belgium, Czechoslovakia, Chile, France, Great Britain, Germany, the Netherlands, Italy, Norway, and Poland. Essential provisions of the agreement are a plan for regulation of production (except for Chile), allocation of markets, and regulation of prices. The present agreement is said to date from July 1, 1930, and will expire June 30, 1931. Each producer is to retain his home market, and export business will be regulated by quota.

The United States necessarily remains outside the cartel, owing to the provisions of the Sherman anti-trust law. However, this country is not a large exporter of nitrogen; and further, no advantage would be gained by an attempt to break the cartel prices, which are set already at low levels.

In order to indemnify those European works that are forced to curtail output below the quotas agreed upon, or that are forced to shut down completely, a fund of £3,000,000 will be set up, £750,000 of which is to be subscribed by the Chilean producers, presumably in return for their own freedom as respects output. The remaining £2,250,000 will be subscribed by the European producers. (It should be noted that £750,000 is equivalent to $1.46 per metric ton of Chilean nitrate, assuming an output of 2,500,000 metric tons during the year 1930-31. This cost must, of course, be absorbed by the Chilean producers.)

About 80 per cent of the world output of nitrogen will be controlled by the parties to the cartel. It is stated that a survey showed that existing nitrogen producing capacity is sufficient to meet world demand for many years. This fact would seem to discourage the construction of new works.

Special agreements have been concluded regulating the import of nitrogen into countries that are parties to the cartel and those outside the cartel. Prices will not be increased beyond the levels of the past fertilizer year. Wherever conditions in the industry permit, price reductions may be expected. While the agreement is for one year, effort will be made during this period to negotiate an agreement covering a long term.

Table IV—World Production and Consumption of Pure Nitrogen for the Fertilizer Years

(In metric tons)

	1924–25	1925–26	1926–27	1927–28	1928–29	1929–30
Production:						
Byproduct sulphate of ammonia	278,300	296,700	328,200	368,000	376,000	380,000
Synthetic sulphate of ammonia	255,000	289,200	200,000	367,000	485,000	455,000
	533,300	585,900	628,200	735,000	861,000	835,000
Cyanamide*	115,000	150,000	180,000	204,000	210,000	263,600
Nitrate of lime	25,000	30,000	81,000	105,000	136,000	130,500
Other forms of synthetic nitrogen†	66,100	120,700	133,400	236,000	365,000	423,000
Other forms of byproduct nitrogen†	47,400	47,700	42,300	54,000	51,000	62,300
Chilean nitrate of soda	367,500	399,400	199,600	390,000	490,000	464,000
Total production	1,154,300	1,333,700	1,264,500	1,724,000	2,113,000	2,178,400
Consumption:						
Consumption of manufactured nitrogen	786,800	934,300	1,037,500	1,249,605	1,452,630	1,596,330
Consumption of Chilean nitrate of soda	363,000	324,200	275,200	392,722	419,450	362,390
Total consumption	1,149,800	1,258,500	1,312,700	1,642,327	1,872,080	1,958,720
Agricultural consumption about	1,020,000	1,117,000	1,200,000	1,490,000	1,684,000	1,721,000

*Excluding part of the cyanamide made in Japan, which is included under synthetic sulphate of ammonia.
†Including ammonia liquor used for industrial purposes.

Table V—Consumption of Pure Nitrogen for Fertilizer Year 1929-30

(In metric tons)

Countries	Ammonium Sulphate	Chilean Sodium Nitrate	Calcium Cyanamide and Ammophos	Other Synthetic Nitrogen Fertilizers	Ammonia for Industrial Purposes	Total
Group 1.—Scandinavia, Russia, Baltic States, Germany, United Kingdom, Holland, Belgium, France, Switzerland, Austria, Czechoslovakia, Hungary, Roumania, Jugoslavia and Bulgaria	353,130	155,950	160,180	281,470	90,000	1,040,730
Group 2.—Spain, Portugal, Azores, Madeira, Italy and Sicily, Egypt and other Mediterranean countries	87,090	65,070	17,040	27,920	3,000	200,120
Group 3.—Indian Empire, Ceylon, Philippines, Straits, Dutch East Indies, Siam, Borneo, Japan, Korea and China	212,480	8,550	30,050	6,900	4,400	262,380
Group 4.—Africa (excluding Egypt) and neighboring islands	3,460	5,540	100	210	270	9,580
Group 5.—United States, Canada, Central and South America, West Indian Islands, Cuba, Puerto Rico and Hawaii	118,600	125,190	36,700	58,190	96,300	434,980
Group 6.—Australasia	7,440	2,090	.....	300	1,100	10,930
Total	782,200	362,390	244,070	374,990	195,070	1,958,720

Table VI—Comparative Figures for Pure Nitrogen for Fertilizer Year 1928-29

(In metric tons)

	Ammonium Sulphate	Chilean Nitrate	Calcium Cyanamid and Ammophos	Other Synthetic Nitrogen Fertilizers	Ammonia for Industrial Purposes	Total
Group 1	346,180	167,780	160,240	263,610	82,430	1,020,240
Group 2	77,170	61,430	13,460	19,920	3,200	175,180
Group 3	195,980	16,860	19,380	7,000	5,680	244,900
Group 4	3,000	3,830	.....	440	270	7,540
Group 5	100,600	167,920	24,400	58,970	65,300	417,190
Group 6	4,730	1,630	.....	270	400	7,030
Total	727,660	419,450	217,480	350,210	157,280	1,872,080

Part of the calcium cyanamide made in Japan is converted into ammonium sulphate and is included under the latter.

The cartel agreement is similar to the Cyanamide Syndicate agreement as regards control of export sales. Domestic sales are in principle reserved to the domestic producers, and exports of countries having a surplus will be separately determined.

Prices will be fixed with compensation for the form and utility of individual products, and not on the basis of nitrogen content alone. Owing to the present relative overproduction of sulphate of ammonia and cyanamide, these products will be the cheapest, and will therefore determine the levels set for other products.

According to a statement of the Société Générale de Belgique, the European production of synthetic nitrogen for the fertilizer year 1930-31 will be limited under operation of the nitrogen agreement to 1,087,100 m. tons, apportioned as follows:

	M. Tons Nitrogen
Germany, U. K. and Norway	840,000
Belgium	73,500
France	75,000
Netherlands	28,400
Italy	39,000
Poland	23,200
Czechoslovakia	8,000
Total	1,087,100

According to "Commerce Reports," Oct. 20, 1930, the consumption of synthetic fertilizer nitrogen in Germany in the year ended June 30, 1930, was 410,000 m. tons, compared with 430,000 tons in 1928-29, and 390,000 tons in 1927-28. Considering the uneasiness caused by cartel negotiations, consumption was fair.

In August, the Merseburg works of the I.G. was reported to be producing at the rate of only 650 m. tons of nitrogen per day, compared with a capacity of 1,800 m. tons per day. During the summer of 1929 the output was nearly double the 1930 figure, or 1,200 m. tons per day. Despite German calculations to the effect that world consumption is increasing at the rate of 200,000 m. tons of nitrogen annually, the I.G. nitrogen outlook is not particularly hopeful. Large stocks of fertilizers are said to be on hand at Merseburg, and it is known that world stocks of competitive fertilizers, particularly of Chilean nitrate of soda, also are dangerously high. The Oppau works is operating on a curtailed schedule of 300 m. tons nitrogen per day, as against a capacity of 350 tons per day.

The present German capacity for nitrogen production is estimated to be about 1,000,000 m. tons per year, distributed as follows:

	Metric Tons
Merseburg Works, I.G.	650,000
Oppau Works, I.G.	100,000
Ruhr coal companies	50,000
Cyanamide producers	100,000
Byproduct cokeries and gas works	100,000
Total capacity, 1930	1,000,000

The Merseburg works alone could, in fact, supply the entire German nitrogen requirements of 400,000 tons for agriculture—100,000 tons for industry—leaving 150,000 tons surplus for export. Therefore the reason the nitrogen cartel negotiations included curtailment provisions of 30 to 40 per cent applicable to Germany is quite apparent. In the meanwhile, the Ruhr Valley producers are proceeding with their program of expansion, and have been granted quotas of 110,000 m. tons for the fertilizer year 1930-31, 140,000 tons for 1931-32, and 160,000 tons thereafter.

The contracts for the continuation of the German Nitrogen Syndicate for seven years, from July 1, 1930, were signed in Berlin on April 7. The composition of the syndicate quotas is as follows:

German Nitrogen Syndicate Quotas 1930-31

	M. Tons of Nitrogen
I. G. Farbenindustrie	750,000
Norsk-Hydro (controlled by I. G.)	90,000
German Ammonia Sales Union, synthetic	110,000
German Ammonia Sales Union, byproduct	91,200
Bayerische Stickstoffwerke (cyanamide)	90,000
A.-G. für Stickstoffdünger (cyanamide)	22,500
East German cokeries (byproduct)	6,000
German Gas Works (byproduct)	6,000
Total of quotas	1,165,700

Syndicate prices for the year 1930-31 are shown in the Table VII. These apply to the German consumer in bulk, minimum lots of 15 tons delivered at nearest railway station. Prices have been reduced on all nitrogenous fertilizer produced in Germany, with the exception of synthetic sodium nitrate. In order to encourage buying in the off-season, prices are graduated upward from a low level in July to the peak, in February. The spread between the low and high prices approximates 15 per cent in the 1930-31 season, as compared with about 11 per cent in 1929-30. No doubt the present large stocks of nitrogen have had a bearing on the establishment of a low base price for the next few months.

Nitrophoska No. 1 is quoted at 25 to 26 marks per 100 kilos, the No. II mixture is quoted at 23.50 to 24.50 marks, and mixture No. III is quoted at 25.50 to 26.50 marks per 100 kilos, the price moving upward with the advance of the consuming season.

Urea is offered at 0.80 to 0.95 mark per kilo of nitrogen, and ammonia chalk nitrate at 0.83 to 0.95 mark per kilo of nitrogen.

British Output Mounts

The striking increase in production of nitrogen in Great Britain is illustrated by the data in Table VIII, taken from the report of the British Sulphate of Ammonia Federation, Ltd.

Analysis of the above figures shows that in the calendar year 1929 the total production of ammonia products was equivalent to 198,000 m. tons of nitrogen. Assuming the products of byproduct nitrogen to be 90,000 m. tons, then the production of synthetic nitrogen was 108,000 m. tons, or exactly 300 m. tons per day. Further, the figures indicate that the combined home consumption of sulphate of ammonia and nitrate of soda for agriculture was equivalent to 46,500 m. tons of nitrogen.

According to the *Chemical Trade Journal*, July 11, 1930, £16,000,000 ($78,000,000) has been expended on the nitrogen plant at Billingham, which plant is now finished and is reported to have a capacity of about 500 m. tons per day of primary nitrogen in form of synthetic ammonia.

France.—According to *Chimie et Industrie*, May, 1930, the French supply of fertilizer nitrogen in metric tons has been as follows:

	1929	1928	1927
Production	74,000	65,000	51,000
Imports	96,000	71,000	82,000
Supply	170,000	136,000	133,000

Table VII—German Nitrogen Syndicate Prices

(In Marks per Kilo of Fixed Nitrogen)

	1928–1929		1929–1930		1930–1931	
Ammonium sulphate, coarse grain	0.85	0.95	0.80	0.90	0.76	0.90
Ammonium sulphate, medium to fine grain	....	....	....	....	0.72	0.86
Ammonium chloride	0.78	0.88	0.76	0.86	0.68	0.82
Ammonia chalk	0.83	0.93	0.79	0.89	0.70	0.84
Ammonium sulphate-nitrate	0.85	0.95	0.83	0.93	0.79	0.93
Montan saltpeter	0.85	0.95	0.83	0.93	0.76	0.90
Potash-ammonium nitrate	0.85	0.95	0.83	0.93	0.79	0.93
Cyanamide	0.78	0.88	0.76	0.86	0.71	0.85
Calcium nitrate	1.13	....	1.03	1.07	0.94	1.07
Sodium nitrate, synthetic	1.23	....	1.13	1.17	1.13	1.17

Table VIII—Nitrogen Production in Great Britain, 1925 to 1929

(Tons of 2,240 lb.)

Calendar Year	Total Production of Ammonia Products Expressed as Sulphate of Ammonia (Basis 25 Per Cent Ammonia)	Fertilizer Year	Production of Sulphate of Ammonia as Such	Exports From U. K. Other Than to Channel Islands and I.F.S. (Customs Returns)	Sulphate of Ammonia Used for Home Agricultural Consumption	Nitrate of Soda Used for Home Agricultural Consumption (Estimated)
1925	445,918	1925/26	377,497	223,210	168,650	35,000
1926	336,456	1926/27	321,913	137,319	169,340	33,000
1927	491,009	1927/28	472,029	302,596	167,720	37,000
1928	644,759	1928/29	645,042	428,437	186,710	49,500
1929	943,068	1929/30	865,878	634,405	183,516	49,500

N. B.—The total consumption of Chilean nitrate is estimated at 57,500 tons, as against 73,000 tons for last season. During the year there was a decline in consumption for industrial purposes.

The composition of production in 1929 in metric tons was as follows:

	Product	Nitrogen
Sulphate of ammonia	275,000	56,000
Calcium nitrate	27,000	4,000
Cyanamide	64,000	12,800
All other	9,000	1,200
Total production nitrogen	.....	74,000

The composition of consumption in 1929 in metric tons was as follows:

	Product	Nitrogen
Sulphate ammonia	420,000	86,500
Cyanamide	70,000	14,000
Calcium nitrate	46,000	7,100
Chilean nitrate	405,000	63,500
Synthetic nitrate soda	25,000	4,000
Total consumption nitrogen	.....	175,100

The growth of the French nitrogen industry is seen in Table IX, in which the estimated production of nitrogen products in 1930 is compared with production in 1913. Production in 1930 was between five and six times that in 1913.

Table IX—French Production of Fertilizer Nitrogen, 1913 and 1930

(In metric tons.)

	1930		1913	
	Tons Product	Tons Nitrogen	Tons Product	Tons Nitrogen
Byproduct sulphate ammonia	141,000	29,000	74,500	15,400
Synthetic sulphate ammonia	215,000	44,300	.....	.....
Cyanamide	80,000	16,000	12,500	2,500
Calcium and am. nitrates	60,000	12,000	.....	.....
All other	10,000	1,500	.....	.....
Total nitrogen produced		102,800		17,900

It is estimated that the Toulouse state-owned plant, which produced 13,000 tons of nitrogen in 1929, produced about 25,000 tons in 1930. The Toulouse plant began operations in the second half of 1928 and had produced about 7,000 tons of fertilizers by the end of 1928. In 1929 the production comprised 51,000 tons of sulphate of ammonia and 6,000 tons of ammonium nitrate or the equivalent thereof. In 1930 the Chamber of Deputies was asked to provide 140,000,000 francs, of which 50,000,000 fr. would be expended on expansion of ammonia plant, and 90,000,000 fr. on nitric acid and fertilizer plant. It is said that the works operated in 1930 without loss, despite the fall in nitrogen prices. The present plant is designed to produce 150 m. tons of nitrogen per day, but actual operation has fallen far short of this figure.

Japan.—A cyanamide cartel (Cyanamide Joint Sales Association) has been formed in Japan, including essentially the entire output (estimated at 150,000 m. tons of cyanamide in 1930), half of which is produced by the Denki Kagaku K.K. The output in 1929 was 180,000 m. tons of cyanamide, half of which was used as such and half converted to sulphate of ammonia. (*Osaka Hiryo Shimbun*, Oct. 3, 1930).

Table X—Sulphate of Ammonia Statistics for Japan

(In metric tons.)

	1929	1928	1927	1913
Production (syn.)	221,800	183,381	158,045	.....
Production (byprod.)	28,600	39,204	29,127	7,342
Total production	250,400	222,585	187,172	7,342
Imports from:				
Great Britain	137,170	96,660	59,740	.....
Germany	179,990	147,060	134,620	.....
U. S. A.	52,960	28,020	40,180	.....
Others	5,280	8,810	11,960	.....
Total imports	375,400	280,550	246,500	109,737
Total supply	625,800	503,135	433,672	117,079
Nitrogen equivalent	129,000	103,700	89,400	24,100
Imports, nitrate of soda	87,866	52,225	52,239	.....
Nitrogen equivalent	13,750	8,170	8,170	.....

The estimated production of sulphate of ammonia in 1929 is 250,000 m. tons, derived from synthetic ammonia, 53 per cent; from cyanamide ammonia, 36 per cent; and from byproduct sources, 11 per cent. Capacity as of Jan. 1, 1931, is estimated to be 450,000 m. tons of sulphate of ammonia, thus indicating marked decline of imports. The course of output and imports is given in Table X.

Imports of miscellaneous nitrogenous materials in 1929 was 100,561 tons, estimated to contain at least 15,000 m. tons nitrogen. Therefore the total supply of nitrogen in 1929 was about 175,000 m. tons, derived as follows:

	Tons Nitrogen
Production sulphate of ammonia	51,300
Imports sulphate of ammonia	77,300
Production cyanamide (used as such)	18,000
Imports nitrate of soda	13,750
Imports other materials	15,000
Total supply	175,350

Exports of nitrogen from Japan are practically negligible, so that the above figure of 175,000 m. tons is not far from the apparent consumption.

Netherlands.—As far as is known, the Sluiskil Works of the Compagnie Neerderlandaise de l'Azote has not begun operations, although scheduled to do so toward the end of 1930. The plant will have a capacity of 200,000 m. tons of sulphate of ammonia per year.

The first atmospheric nitrogen plant in the Netherlands, at Ijmuiden, began operations in September, 1929. At present, production is limited to sulphate of ammonia, although it is planned to produce calcium nitrate and diammonium phosphate.

The Netherlands nitrogen industry was allotted 91,000 tons of nitrogen in the recent cartel, this quantity being distributed as follows: state mines at Limburg, 26,000 tons; the Ijmuiden plant, 13,000 tons; and the Sluiskil plant, 52,000 tons. The large quotas to the synthetic ammonia plants indicate that actual production will be greater than has been announced.

Table XI—Consumption of Fertilizer Nitrogen in the Netherlands

(In metric tons.)

	1928–29		1927–28	
	Tons Product	Tons Nitrogen	Tons Product	Tons Nitrogen
Nitrate of soda	132,000	21,100	84,000	13,400
Sulphate ammonia	130,000	26,800	118,000	24,300
Calcium nitrate	67,000	10,400	45,000	7,000
Leunasalpeter	15,000	3,900	13,000	3,400
Cyanamide	9,000	1,800	.....	.....
Others	4,200	1,900	5,000	600
Total tons nitrogen		65,900		48,700

Italy.—At the end of 1929, production capacity of Italian nitrogen plants is reported (by *Revue des Produits Chimiques*, Oct. 31, 1929) to be as follows:

	M. Tons Nitrogen
Synthetic ammonia	44,000
Cyanamide	20,000
Byproduct sulphate of ammonia	3,000
Total capacity	67,000

In 1929 estimated production of cyanamide was 75,000 m. tons (15,000 m. tons nitrogen); and 122,000 m. tons sulphate of ammonia (25,000 m. tons nitrogen).

The consumption of nitrogen fertilizers in Italy is increasing rapidly, as is indicated by Table XII, derived from "Italian Chemical Developments in 1928 and 1929," U. S. Dept. of Commerce Trade Information Bulletin No. 705.

It is interesting to note that despite apparent ability of Italy to meet all nitrogen requirements from domestic plants, consumption of imported fertilizers, principally nitrate of soda, is on the increase.

Norway.—According to *Chemische Industrie*, Aug. 16, 1930, the Norwegian output of nitrogen products is that shown in Table XIII.

Table XII—Consumption of Nitrogen Fertilizers in Italy

(In metric tons.)

	1929		1928		1927	
	Tons Product	Tons Nitrogen	Tons Product	Tons Nitrogen	Tons Product	Tons Nitrogen
Cyanamide	97,300	19,500	78,000	15,600	62,330	12,500
Sulphate of ammonia	122,660	25,300	107,500	22,100	81,400	16,800
Nitrate soda	74,000	11,600	58,000	9,100	38,500	6,000
Leunasalpeter	21,650	5,600	17,000	4,400	11,754	3,000
Calcium nitrate	31,360	4,900	12,300	1,900	3,786	600
Total tons nitrogen		66,900		53,100		38,900

Table XIII—Norwegian Production of Nitrogen Products

(In metric tons.)

	1928 Tons Product	1928 Tons Nitrogen	1927 Tons Product	1927 Tons Nitrogen
Calcium nitrate	173,337	26,900	159,120	24,700
Nitrate soda	37,815	6,000	29,921	4,800
Nitrite soda	2,317	500	3,726	700
Ammonium nitrate	13,823	4,800	10,230	3,600
Nitric acid	9,092	2,000	7,933	1,800
Cyanamide	58,363	11,700	51,260	10,300
Total tons nitrogen		51,900		45,900

It is believed that during 1929 the output of nitrogen must have been much greater than in 1928. The new synthetic ammonia works of the Norsk Hydro has a rated capacity of about 90,000 m. tons of nitrogen per year, and this, together with the various cyanamide works, will give Norway a capacity well above 100,000 m. tons of nitrogen per year. If the greater part of the nitrogen is sold as calcium nitrate, as much as 500,000 tons of this fertilizer could be produced annually, an increase of 300,000 tons over the capacity of the old arc process plant.

Poland.—Synthetic ammonia projects are being pushed with the apparent idea of making Poland self-contained as respects nitrogen requirements. The new plant at Tarnow, which began operations in 1929, has a capacity of 18,000 m. tons of nitrogen per year. It was built by the government at a cost of about $12,000,000, and has facilities for fertilizer manufacture as well as the basic synthetic operations. About 60 tons per day of ammonia will be converted to sulphate of ammonia (60 tons) and ammonium nitrate (100 tons).

The capacity of the new Moscice works will be 86,000 tons of nitrophos (15½ per cent nitrogen) and 15,000 tons sulphate of ammonia, or a total of 16,000 tons nitrogen per year (54 tons ammonia per day). The Knurow plant produced 12,000 tons sulphate of ammonia in 1928, using the Claude ammonia synthesis. The synthetic ammonia works at Vyry was started up in 1929 and will have a capacity of 25 tons ammonia per day, half of which will be converted to sulphate of ammonia. The Chorzow works, which heretofore produced only cyanamide nitrogen, is starting other fertilizer operations, including a new synthetic ammonia plant having an estimated capacity of 20-25 tons ammonia per day. One of the fertilizer products of Chorzow will be nitrate of soda, to be produced at the rate of 25,000 tons per year. Ammonium chloride will be produced simultaneously, in conjunction with soda ash operations.

It would appear that these five ammonia synthesis projects when operating at full capacity, could produce from 150-175 metric tons ammonia per day. In addition, the government-owned Chorzow cyanamide plant can produce about 200,000 tons of cyanamide (40,000 tons of nitrogen) per year.

In 1927 the byproduct nitrogen production in Poland was 4,600 m. tons, but it is expected that in 1929 the production was increased to 8,000 m. tons, due to increased activity of the Upper Silesian coke ovens. Thus the total nitrogen capacity of Poland will soon be about 100,000 m. tons per year, which is much in excess of present requirements. (See Table XIV.)

Table XIV—Fertilizer Nitrogen Consumption in Poland

(In metric tons.)

	1929 Tons Product	1929 Tons Nitrogen	1928 Tons Product	1928 Tons Nitrogen
Nitrate of soda	128,000	20,000	98,000	15,300
Cyanamide	137,000	27,400	127,000	25,400
Ammonium nitrate	5,000	1,700	6,000	2,100
Sulphate of ammonia	32,000	6,600	20,000	4,100
Total tons nitrogen		55,700		46,900

Czechoslovakia.—According to U. S. Dept. of Commerce Trade Information Bulletin No. 708, the consumption of fertilizer nitrogen in Czechoslovakia is that shown in Table XV.

The Falkenau plant of Aussiger Verein, which started production in 1918, has a capacity of 35,000 m. tons of cyanamide per year. The power consumption is 11 kw.-hr. per kilogram nitrogen fixed. The Marienberg plant of the Czechoslovak Nitrogen Works (partly owned by Aussiger Verein) produces 30 m. tons of ammonia per day and has a rated capacity of 60 m. tons. The byproduct ovens of the Moravian-Ostrava coke plants can produce 40,000 tons of sulphate of ammonia per year. Thus the capacity of domestic nitrogen sources is about 33,000 m. tons of nitrogen per year.

The actual production of nitrogen fertilizers in 1929 was as follows: sulphate of ammonia, 70,370 m. tons; cyanamide, 27,038 m. tons. Imports of nitrate of soda in 1929 totaled 99,000 tons, less than half of which was consumed, however.

Russia.—The Koksobenzol Trust, of Charkov, has contracted for the construction of a synthetic ammonia plant at Gorlovka. This will have a capacity of 100 tons of ammonia per day. Coke-oven hydrogen will be used in a Fauser system. The ammonia will be converted to sulphate by the new Fauser process (direct production of dry granular sulphate by spraying sulphuric acid into large towers containing ammonia gas).

According to the *Journal of Chemical Industry,* Moscow, Dec. 15, 1929, the output of ammonia products is that shown in Table XVI.

Table XV—Fertilizer Nitrogen Consumption in Czechoslovakia

(In metric tons.)

	1928-29 Tons Product	1928-29 Tons Nitrogen	1927-28 Tons Product	1927-28 Tons Nitrogen	1926-27 Tons Product	1926-27 Tons Nitrogen
Sulphate ammonia	55,634	11,500	42,475	8,800	41,567	8,600
Nitrate of soda	46,435	7,300	71,675	11,200	42,334	6,600
Calcium nitrate	11,573	1,800	11,043	1,700	7,019	1,100
Cyanamide	37,406	7,500	30,036	6,000	22,664	4,500
Total tons nitrogen		28,100		27,700		20,800

Table XVI—Russian Production of Ammonia Products

(In metric tons.)

	1928-29 Tons Product	1928-29 Tons Nitrogen	1927-28 Tons Product	1927-28 Tons Nitrogen
Ammonia liquor (as NH_3)	5,345	4,400	4,049	3,300
Byproduct sulphate of ammonia	14,586	3,000	12,564	2,600
Sulphate from chemical industry	4,437	900	848	200
Total tons nitrogen		8,300		6,100

Recent accounts state that Russia is purchasing nitrate of soda for use in agriculture, indicating that substantial increase in nitrogen consumption may occur in the next few years.

Sweden.—In 1928 the Swedish production of inorganic nitrogen was about 4,600 m. tons, comprised as follows:

	M. Tons Product	M. Tons Nitrogen
Cyanamide	13,415	2,680
Ammonia liquor (as 25 % NH_3)	650	134
Ammonium nitrate	312	109
Ammonium sulphate	7,610	1,570
Nitric acid (as HNO_3)	466	103
Total nitrogen		4,596

According to a British Department Overseas Trade Report of April 16, 1930, the production of sulphate of ammonia in gas works was 12 to 13,000 tons in 1929, as against 7,610 tons in 1928. Assuming production of other products remained the same as in 1928, the total nitrogen production in 1929 would be 5,600 m. tons. It is understood that during 1929 the Ljunga works began operation of a Fauser synthetic ammonia plant which has a capacity of 10,000 tons of sulphate of ammonia (2,000 tons nitrogen) per year.

Spain.—In 1928 the production of sulphate of ammonia was 21,638 m. tons, about half of which is from byproduct sources, and half from the synthetic ammonia plants of the Sociedad Iberica del Nitrogeno at La Felguera and Flix. Increase in consumption of nitrogen is indicated in Table XVII.

Table XVII—Consumption of Fertilizer Nitrogen in Spain

(In metric tons.)

	1928 Tons Product	1928 Tons Nitrogen	1913 Tons Product	1913 Tons Nitrogen
Nitrate of soda	140,150	21,900	35,235	5,500
Sulphate of ammonia	239,882	49,400	102,723	21,200
Cyanamide	1,509	300	.....	.....
Other products	9,361	1,400	.....	.....
Total tons nitrogen		73,000		26,700

Chemicals Compete for the Refrigerant Market

By J. B. Churchill
Consulting Engineer
New York City

FEW of the many compounds known to the chemical industry have physical properties that fit them to be used as refrigerants, or, in other words, possess the property of passing from a liquid to a gaseous state when heat is applied at low temperatures and pressures, and to discharge this heat when compressed from a gas to a liquid under higher temperatures and pressures.

Looking back over the history of mechanical refrigeration, we find that perhaps 50 different substances or mixtures have been at one time or another used as refrigerants in compression or absorption machines. Time and experience have eliminated the major part of these, and we find the list has been continually narrowed until today there are comparatively few substances to which we might apply the term of "commercial refrigerant." These are as follows: ammonia, sulphur dioxide, carbon dioxide, methyl chloride, ethyl chloride, ethane, propane, butane, isobutane, methylene chloride, dichlorethylene, and trichlorethylene; and we might add to this group the two of our commonest substances: namely, air and water.

A complete discussion of the physical properties of refrigerants is given in Circular No. 2 published by the American Society of Refrigerating Engineers, entitled "Properties of Refrigerants," and more detailed data of the pressure temperature and other thermodynamic properties of refrigerants will be found in Circular No. 9 of the same society, entitled, "Tables of the Thermodynamic Properties of Steam Refrigerants and Brine."

Previous to 1920 the only chemicals that were used to any considerable extent as refrigerants were ammonia and carbon dioxide. Since that time, however, we find that a tremendous development has taken place in the use of household-refrigeration machines, and this has caused a demand for substances more suitable for use with machines of a fractional ton capacity. Our chemical industries, with their increasing demand for low-temperature refrigeration, and also the extensive application of refrigeration to commercial air-conditioning have created an interest in refrigerants other than ammonia and carbon dioxide.

Before the application of the small refrigerating machine to household refrigeration, the chief factors entering into the choice of a proper refrigerant were concerned almost entirely with its having the proper physical properties to admit of reasonable construction of the refrigerating machinery. The risks were almost entirely occupational and the use of refrigerating machinery was confined almost wholly to large commercial plants built for ice making or cold storage purposes. The employees in such establishments were thoroughly trained and alert to all possible dangers resulting from leaks in the equipment—the buildings especially constructed to permit easy exit, and the risk involved was wholly an occupational one.

Household refrigeration, however, has introduced a different phase and a different risk; namely, an occupancy risk or hazard. The occupants of the apartments or dwelling houses in which this type of apparatus is installed have little or no knowledge of the safety or type of apparatus used or the sort of refrigerant employed, and generally they have no means of judging the effect or even the extent of a leak should it occur. This condition has during the last decade focused the attention of the public, as well as the refrigeration industry, upon the question of safety, and has emphasized the importance of careful consideration of the danger from poisoning or other hazards which may be incurred by the use of any specific refrigerant.

Data on the relative toxicity by weight of various refrigerants are presented on page 9 of Circular No. 2

Table I—Physical Properties of Common Refrigerants

Name	Ammonia	Sulphur Dioxide	Methyl Chloride	Ethyl Chloride	Carbon Dioxide	Ethane	Propane	Butane	Isobutane
Chemical Formula..	NH_3	SO_2	CH_3Cl	C_2H_5Cl	CO_2	C_2H_6	C_3H_8	C_4H_{10}	C_4H_{10}
Molecular weight....	17.03	64.06	50.49	64.50	44.01	30.06	44.08	58.10	58.10
Boil'g point at 1 atm.	—28.03	14.0	—10.65	53.9	—109.4	—126.9	—48.1	33.1	13.6
Melting point (solid)	—107.8	—103.4	—132.7	—217.7	—109.3	—277.6	—309.8	—211.0	—229
Critical temperature	271.2	314.8	289.6	360.0	88.4	89.8	204.1	303.4	272
Critical press. (abs.).	1651.	1141.	970.0	784.	1071.	718	661.	551.3	537.
Density of liquid at 32° water = 1.....	0.638	1.44	0.952	0.920	1.56	0.446	0.536	0.601	.....
Density gas lb/ft.³ 32° 1 Atm.....	0.0517	0.1827	0.1438	0.2276	0.1234	0.0846	0.1260	0.1619	.....
Density gas at 32° 1 atm. air = 1.....	0.596	2.264	1.782	2.31	1.528	1.049	1.562	2.067	.....
Specific heat constant pressure.....	0.520	0.511	0.24	0.273	0.2025	0.397	0.365	0.351	.....
Specific heat constant volume.....	0.401	.....	0.20	.....	0.1558	0.324	0.361	.....	.....
Ratio CP/CV.....	1.297	1.256 (16–34°)	1.199 (68°)	1.126 (163°)	1.3003 (32°)	1.224 (50°)	1.153	.....	.....
Comparative volume displacement per unit of refr'g'rtion	5.77 / 1.0	15.1 / 2.61	11.6 / 2.01	37.0 / 6.41	1.0 / 0.17	1.7 / 0.30	5.8 / 1.01	12.7 / 2.20	..... / .....
Standard ton data	5° 86°	5° 86°	5° 86°	5° 86°	5° 86°	5° 86°	5° 86°	5° 86°	5° 86°
Gage pressure.....	19.6 154	5.9* 51.8	6.2 80.8	20.1* 12.40	319 1024	221 666	30.4 143	13.2* 26.9	3.3* 44.8
Vol. liquid ft.³/lb....	0.0243 0.0269	0.0108 0.0118	0.0163 0.0179	0.0169 0.0182	0.0163 0.0267	0.0365 0.0569	0.0291 0.0329	0.0260 0.0283	0.0268 0.0294
Volume vapor ft.³/lb.	8.15 1.77	6.42 1.18	4.53 1.07	17.06 3.29	0.2673 0.0474	0.629 0.122	2.34 0.681	9.98 2.24	6.41 1.52
Density liquid lb./ft.³	41.1 37.2	92.0 84.4	61.0 55.8	59.0 54.88	61.22 37.41	27.4 17.8	34.3 30.4	38.4 35.4	37.4 34.10
Density vapor lb./ft.³	0.122 0.564	0.156 0.844	0.220 0.930	0.058 0.304	3.74 21.09	0.690 0.122	4.27 1.47	0.1000 0.446	0.156 0.658
Heat liquid Btu/lb..	48.4 138.9	14.11 42.12	21.2 59.3	—11.6 23.1	—13.16 45.45	....	3.0 51.0	2.5 48.5	2.5 50.5
Heat latent Btu/lb..	565.6 492.6	169.4 142.8	178.5 162.9	177.0 162.6	115.3 27.00	176 70	169.5 144.0	169.5 153.5	159.5 131.0
Heat vapor Btu/lb..	613.5 631.5	183.5 184.9	199.7 222.3	165.4 185.7	102.1 72.46	....	172.5 195.0	172.0 202.0	162.0 189.5

*Inches of mercury below one standard atmosphere. (29.82 in. = 14.696 lb. abs.) All temperatures-degrees F.
This table is based principally on the data presented in the two circulars mentioned in the text, and the International Critical Tables.

ing Engineers, already mentioned. This gives the relative concentration by gives the relative concentration by weight of vapor of the various refrigerants in a room of given size to produce the same effect. This is:

Carbon Dioxide	100
Ethyl Chloride	80
Methyl Chloride	70
Ammonia	2
Sulphur Dioxide	1

And the relative toxicity of many refrigerants also is given in Public Health Bulletin No. 185, published by the U. S. Public Health Service, in 1929.

Before discussing the individual groups of refrigerants, an approximate survey might be of interest. In the commercial field we find some forty firms manufacturing machinery using ammonia, and about ten using carbon dioxide. In the household field, or domestic division, of refrigeration, about 30 manufacturers are producing machines using methyl chloride, and about the same number use sulphur dioxide. However the total number of machines using sulphur dioxide outnumber all others and require 60 to 70 per cent of the refrigerants in this field. One machine manufacturer uses air, one water, and one isobutane. Several other firms are using refrigerants to which they give trade names, but their production is so small that they may be considered of no consequence from the point of view of the manufacture or consumption of refrigerants.

Commercial Refrigerants

For the purposes of commercial refrigeration, we find carbon dioxide and ammonia occupying the entire field. For a long time carbon dioxide has been a favorite for marine refrigeration and for special purposes where an odorless and non-flammable refrigerant is desired. It is extremely stable, but it is not adaptable for refrigeration where the temperatures of the cooling water is high. Its critical point is the lowest of all refrigerants, being about 88 deg. F.

For nearly three-quarters of a century ammonia has been the most important chemical used for refrigeration purposes, both with the compression type of machines, where anhydrous liquid ammonia has been used, and in the absorption machines, where strong aqua ammonia has been used as the refrigerant. The chemical and physical properties of ammonia are such as to make it the most adapted for commercial refrigeration. It probably is not an exaggeration to state that 90 per cent of all the world's production of refrigeration has been supplied by machines using ammonia as a refrigerant. In the household field also we find ammonia used successfully.

In the field of household refrigeration we find methyl chloride and sulphur dioxide as the principal refrigerants used. Ethyl chloride has been used to some slight extent in this field, as also has isobutane, one of the hydrocarbon refrigerants.

The use of sulphur dioxide has been almost completely confined to the household field. At the beginning of the development of the domestic refrigeration industry as a commercial business, we find that sulphur dioxide was the only refrigerant suitable and available to the manufacturer of the small household machine, and this fact more than any other accounts for its extensive use in this field at the present time. Sulphur dioxide is the most highly toxic of any refrigerant employed. It has no corrosive effects on metals, if entirely dry, but traces of moisture result in the formation of sulphurous acid, which results in corrosion. This has caused considerable trouble in the past. The advocates of the use of sulphur dioxide consider that its obnoxious odor is a distinct advantage in that it constitutes its own warning agent in a case of accident.

Methyl Chloride

Methyl chloride was introduced as a refrigerant in the United States before 1920, but in Europe its use had earlier become general and it was well recognized that it was especially adaptable for fractional-ton refrigeration, and was considered the most practical and safe substance to use as a refrigerant where the risk was one of occupancy. Since the date of its introduction methyl chloride has had a slow but gradually increasing use as a refrigerant. Although its use has been confined principally to the household machine, we find at the present time that it is being favorably considered for plants having a capacity of several tons. Methyl chloride is nearly odorless, is non-corrosive, and relatively non-toxic, and its physical properties render it especially adaptable to machines ranging in capacity from 100 lb. or less of refrigeration in 24 hours up to five tons. It is extremely stable and does not become corrosive when mixed with traces of moisture.

Ethyl chloride has two distinct disadvantages as a refrigerant. First, it is highly flammable and a number of fatalities have resulted from its use as a refrigerant in domestic machines. Secondly, machines using ethyl chloride have the disadvantage of having their low side operate under less than atmospheric pressure, rendering them liable to accidents produced by the leaking in of air. While this refrigerant was considerably used a few years ago, its use has been almost entirely discontinued.

During the past few years, considerable interest has centered around the possibility of the use of the so-called hydrocarbon refrigerants; these comprise ethane, propane, butane, and isobutane. Only one of these, isobutane, has been used for general refrigeration purposes, and its use was confined to one or two manufacturers of small household machines. Ethane and propane are both admirably suited for the production of low temperatures in industrial plants where proper measures can be taken as safeguards against fire or explosive risks. Many thousand tons of refrigeration per day are being produced in our commercial industry, in which ethane and propane play the part of refrigerant.

High boiling refrigerants include carbon tetrachloride, dichlormethane, dichlorethylene, and trichlorethylene. All of these are liquids at the ordinary temperature and pressure and have boiling points under normal conditions considerably over 100 deg. F. Their use is almost exclusively confined to the so-called high-temperature or air-conditioning refrigeration, where large rotary machines operating under vacuum on both high and low sides are economical. At the present time methylene chloride is the most important member of this class of refrigerants.

In April, 1930, at the Atlanta meeting of the American Chemical Society. Thomas Midgley, Jr., of the General Motors Company, announced a new refrigerant, dichloro-difluoro-methane. This substance was first described by Swartz, of Belgium, in 1907. Midgley has described this, as well as other refrigerants of the same class, and has given its most important physical characteristics, as well as a description of the investigations of the U. S. Bureau of Mines, which show this substance to be practically non-toxic and non-flammable. It is stated that this material will be available as a commercial commodity in the near future and that preparations are being made to manufacture it on a large scale. It would be idle to predict to what extent this new substance will be used or will replace other refrigerants.

A Prediction

It would be hazardous to predict with any degree of confidence what refrigerants will hold the leading place in the industry through the coming years. It would be my prediction, however, that ammonia will continue to be the leading refrigerant used in large commercial equipment, with carbon dioxide as its only important competitor in this field, and that we may expect the relative amount of refrigeration produced by each of these to remain practically in the same proportion as at present. In the domestic field it would seem to me as if methyl chloride is almost certain to be adopted as the most generally used refrigerant and that the market for sulphur dioxide, which may possibly show an increase during the next few years, will gradually decline in favor of the former, which will occupy the same place here as ammonia does and will in the commercial field.

How Competition Is Affecting

Paint and Varnish

Materials and Processes

Editorial Staff Review

A DECADE ago the paint and varnish industry was enjoying a tranquil existence, but like many other industries the economic conditions existing at the end of the World War were the cause of a rapid awakening. Quick-drying nitrocellulose lacquers and lacquer enamels (pigmented lacquers) rapidly replaced the oleoresinous varnishes and varnish enamels (pigmented varnishes) for automobile and largely for furniture finishes. This was soon followed by the development of the quick-drying varnish vehicles and still later by the synthetic resin-type lacquers. Raw materials, also, changed rapidly during this period; white lead had enjoyed an enviable position until zinc and titanium oxides and lithopone aggressively entered the pigment market. And solvents too have taken part in this kaleidoscopic situation. The new synthetic resins are soluble in mineral spirits, solvent naphtha, and other low-priced solvents, and as a consequence are cutting into the demands for the nitrocellulose solvents. And drying oils are losing much of their popularity to the partly polymerized synthetic resins, both for primer coatings and finishes.

Nitrocellulose lacquers had been used for several decades prior to the war, but because of their high viscosity, only a relatively small quantity of nitrocellulose could be dissolved per gallon of solvent to produce a finishing material of practical working viscosity.

Lacquer Substituted for Varnish

The development of low viscosity nitrocellulose made it possible to multiply the nitrocellulose content many times over per gallon of solvent and still produce a practical finishing material. This development, making possible a film containing a large percentage of nitrocellulose solids, opened up an avenue for their use, both for exterior purposes on automobiles and also on furniture.

Quick-drying nitrocellulose lacquers entered this market extensively in 1923. Their use spread slowly, because the cost per gallon was appreciably higher than that of the commercial furniture varnishes and because industry had to adjust itself to the new methods of application. By this time the automobile industry was manufacturing great quantities of cars and had become a large user of paint and varnish products. As the production of cars increased, the problem of speeding up the time of finishing likewise increased in importance, and because of this fact the industry was quick to adopt the rapid-drying nitrocellulose lacquers, and by 1927 every automobile and many furniture manufacturers had substituted lacquer for varnish.

Limitations of Lacquers

Varnish producers not only lost these tremendous markets for their products but the lacquers and lacquer enamels had caught the favor of the public and their use spread rapidly to other important applications. The rolling stock of railroads became a market for these nitrocellulose lacquers and the architectural use grew, although not so rapidly. But the labor unions have since been responsible to a major extent for the practical disbarment of lacquer for architectural uses.

Of itself the nitrocellulose film is not a desirable product on wood, because it is a "tight" film and not adaptable to the several radical changes which wood undergoes in the course of the various seasons of the year, which is different from the uniform and relatively slight contraction and expansion of metal. The result has been a constant recession in the use of strictly nitrocellulose lacquers on wood products. The wood-product manufacturer has returned either to varnish or synthetic resin type finish.

Nitrocellulose lacquers made production possibilities never dreamed of before, and as the users were highly pleased with the speed possible from them, the result has been a stimulation toward decidedly faster drying products. As a consequence of this demand for faster drying products the varnish producers set to work to increase the drying time of their products, while retaining all other properties. Simultaneously work was directed in the line of combining other elements with nitrocellulose bases to compensate for the deficiencies of the lacquer, while retaining the benefits which are still unique with nitrocellulose lacquers. The result has been the substitution of synthetic resins in place of the natural resins in both varnishes and lacquers. These resins accelerate drying, because of their faculty of ridding themselves quickly and completely of solvents.

This development supplied a quick-drying varnish and permitted the use of cheaper solvents and smaller quantities of nitrocellulose. Low-boiling coal tar and petroleum distillates are adaptable with them, replacing the more costly turpentine.

Another development in this connection is synthetic resins of the incompletely polymerized type, which are being developed to form films by themselves—when applied mixed with solvent and sometimes with pigments. In these products less drying oil is employed, although some linseed and china wood oils are still used. These synthetic-resin-base materials have already entered into competition with the natural resin products for the automobile trade and one large car manufacturer is now using them.

Although the value of the products of the paint, varnish, and lacquer industry increased from $274,000,000 in 1921 to $550,000,000 in 1929—more than doubled—the oleoresinous varnishes increased from $29,033,763 to only $46,770,367; in other words, these products did not keep pace with the industry as a whole. On the other hand, pyroxylin products, which were not used in the industry in 1921, became popular soon after that year, and in 1929, 41,000,000 gal. was consumed in the production of lacquers.

Competition Among Pigments

The change from paints and varnishes for automobile and other fine-article finishing necessitated almost as fundamental a change in pigment habit as it did in vehicle and solvent habit. Although the industry as a whole doubled during the years from 1921 to 1929, white lead was in smaller demand in the latter year when only 530,802,000 lb. was produced, as compared to 584,360,000 lb. in 1921.

White lead is the oldest of all white pigments and for many years it was the only white pigment in use, but it now has three important competitors: zinc

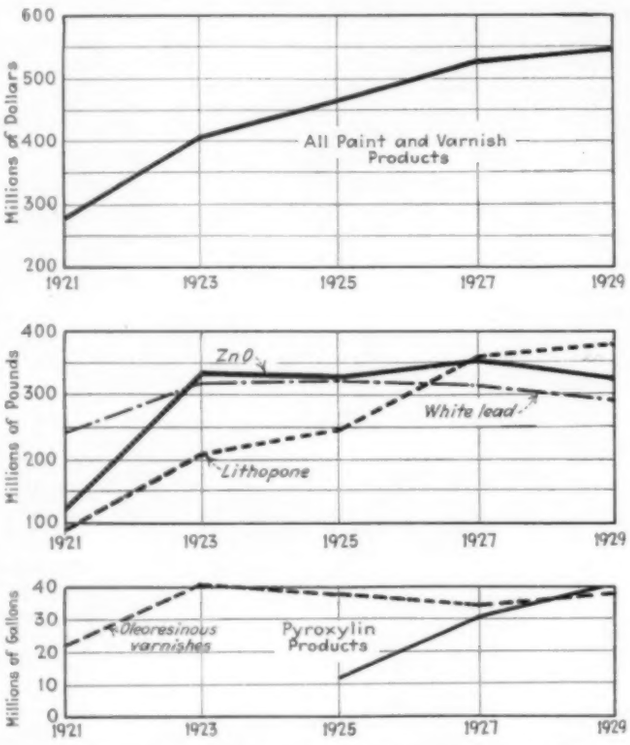
oxide, titanium oxide, and lithopone. White lead is generally considered to give a more elastic paint and therefore a more durable one. Zinc oxide is the chief anti-chalking white pigment; titanium oxide has the greatest hiding power; and lithopone is the cheapest of the common white pigments. Because of the ability of white lead to give elasticity to the product in which it is an ingredient, it has a definite function and will continue more or less of a staple, like bread or sugar.

Zinc oxide has been used in only a limited amount until recent years. In 1921, 124,000,000 lb. was produced in this country, most of which was consumed in paints and varnishes, and in 1929 the amount had increased to 321,000,000 lb. more than double the 1921 figures.

The tremendous growth in the lithopone industry from a production of 20,000,000 lb. in 1902, to 96,000,000 lb. in 1921, and 382,000,000 lb. in 1929, testifies to the progress of this pigment. Its popularity was retarded during the first few years, due to the property it then had, of suddenly turning dark on exposure to sunlight. Within the past 10 or 12 years this pigment has come into its own, and today there is probably no paint manufacturer in this country who does not use it. Lithopone has taken most of the market for pigments for interior finishes from white lead. Much of the present production is for flat wall paints, for it can be mixed with tung oil-rosin varnishes without bad effect and it has the advantages as far as freedom from mechanical defects that other white pigments have. As a first coat white or as a pigment in the lighter shades for floor paints, it has been substituted to some extent for white lead. And, mixed with zinc oxide, lithopone is competing with white lead for the exterior paint trade and may further reduce the demand for it.

Titanium oxide was first used as a white pigment on a commercial scale about 1920. It has been estimated that the total production in 1929 was about 6,000,000 lb. Although the production of titanium oxide has been small as compared with the other white pigments already mentioned, it is very important and its success is closely watched by producers of the other pigments. Present indications point to a much more rapid growth of the titanium pigment industry. Another large plant is about ready to go into production in Virginia. A most important incident occurred in December when the producers of titanium oxide pigments lowered the price from 7½ to 6¾ cents per pound. The significant part of this reduction was the fact that the manufacturers of this material had customarily followed the reductions in the price of lithopone, and this was the first instance where the titanium oxide producers assumed the initiative. They were followed almost immediately by the lithopone producers, who made a reduction of 15 per cent in the market price of their product.

Titanium pigments are necessary in some products and have resulted in the development of new colored pigments to accompany them, as some of those that are customary with lead and zinc do not work well with the titanium base. It appears that this change, like the substitution of solvents, plasticizers, and the like for drying oils, again illustrates the far-reaching consequences of a new research development.



Trends in Production and Value of Raw and Finished Paint, Lacquer and Varnish Materials

Although the production of red lead has increased from 47,810,000 lb. in 1921 to 79,842,000 lb. in 1929, its rate of increase has not kept pace with the industry as a whole. Many products have entered into competition with it for paints for use on structural steel, its chief outlet. Among these are graphite, coal tar derivatives, asphalt, and iron oxide paints. And there are others of less importance.

Previous to about 1907 linseed oil was practically the only drying oil in use, but about that time methods were developed for avoiding the polymerization in china wood oil that normally occurs at comparatively low temperatures, and its use expanded rapidly until today it is the basis for many of the oil varnishes and enamels. The total importation of this oil in 1927 according to the U. S. Department of Commerce amounted to 89,650,411 lb.

Paints and long oil varnishes constituted the field for the drying oils, but with the advent of the nitrocellulose lacquers, the quick-drying varnishes, and the synthetic resin lacquers, the demand for linseed oils has rapidly diminished. Constantly smaller and smaller quantities of drying oils are being used in the vehicles; in their place the partially polymerized synthetic resins are used.

The demand for quick drying base coats has developed the synthetic resin primer coats for use with both lacquers and quick drying varnishes. The synthetic resins have replaced drying oils. On a price basis these new base materials are much cheaper than lacquers for interior work. It would not be surprising in a few years to find linseed-oil-base materials no longer used for automobile finishes.

Coincident with the lacquer development there has been a remarkable expansion in the production of numerous solvents. In its use it is absolutely vital that what is known as a high boiling solvent be used. Such a solvent evaporates very slowly and keeps the nitrocellulose in solution until all the quicker drying solvents have evaporated. Prior to the war, the only foolproof solvent of this character was amyl acetate, a byproduct of the distilling industry. Its supply was limited; it was expensive—almost prohibitive for some commercial uses—and prohibition in our country further reduced the supply.

A synthetic product, butyl alcohol, was developed by a bacteriological process from corn. Butyl acetate was readily made from this and proved a satisfactory substitute for amyl acetate, both from the standpoint of supply and cost.

Both butyl and ethyl alcohol and, to a lesser extent, amyl alcohol are the bases for many solvents that are essential in the production of lacquers. Among these are ethyl, butyl, and amyl acetates, ethyl lactate, diethyl and diamyl phthaletes. In the synthetic-resin-type varnishes, the high-boiling coal-tar solvents are used, but the supply is limited and other suitable solvents must be developed to supply the demand.

In closing, it might be well to call attention to the competition that the paint and varnish industry is receiving from chromium and nickel plating, stainless steels, and plastics. Articles made of these materials will not require finishes and will thus reduce the demand for them.

Economic Problems Now Hold Ascendancy in Rayon

IN COMMON with all products that enter into the operations of highly organized industries such as textiles, the synthetic fibers form a nucleus of many interacting and frequently changing forces which must constantly be evaluated by the manufacturer. But before examining these factors it is desirable to look into the present status of the industry, which has discovered, during the past 18 months, that economics rather than technology dominates its present situation.

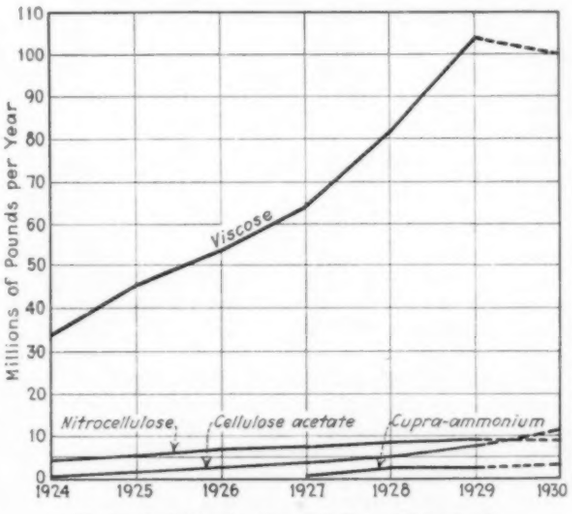
Little was newly evident in the technical position of the rayon industry during 1930 that might be used as a basis for prediction. The year and a half just completed is notorious, principally, for a badly disorganized price situation. Quotations had previously been stabilized at $1.30 per pound of 150 denier, first-quality rayon for 16 months preceding June, 1929; but since that date they have slumped twice, finally reaching a *quoted* figure of $0.95 in July, 1930. How well the quoted price has been maintained is unknown, although it is admittedly nominal.

Information on 1930 rayon output is scanty and uncertain. Producers were much less willing than formerly to supply production figures, and *Textile World*, in preparing its preliminary estimates for the year, based its results on the first seven months, with a proviso that later downward revision might be necessary. The preliminary figure of 130,369,000 lb. produced in the United States now appears to have been high by 6 to 8 per cent, and the best estimate that can yet be made for the year is about 120-125 million pounds, or approximately equal to the revised estimate of 123,130,000 lb. in 1929. This indicates that the industry operated at roughly two-thirds capacity. Simultaneously imports, judged from the record of 11 months, have added 6,000,000 lb., which, when offset against a probable consumption roughly 12 per cent below production, shows a production excess approaching 16,000,000 lb. Exports, estimated at 375,000 lb., obviously can have little effect on this figure. Appraising the foreign situation, one finds the United States apparently holding its earlier position as producer of approximately one-third of the world total.

Trends in technology during the year have shown no new developments of a very spectacular nature. Emphasis has been placed principally on cost reduction and has taken the direction of caustic recovery by dialysis, improved solvent recovery, and a gain in popularity of bobbin spinning at the expense of the pot method, because of the former's suitability for pressure and vacuum washing. Much improved equipment has become generally available, but it is difficult to determine what effect it may have had, since the larger producers, in the main, develop their own machinery.

In their competitive aspects, both manufacture and sale of synthetic fibers are fraught with interesting possibilities. One feature is rayon's position as a new and different fiber with properties possessed by no other material. Once it had lost its early stigma of "substitute" and was able to travel on its own merits, it uncovered many hitherto unknown markets and found its earlier growth less a matter of replacement than of addition to existing lines.

As production grew, however, rayon naturally began to encroach upon other markets, and it must now compete for a considerable part of its business with silk, cotton, and wool. Development of delustered products, approaching silk in appearance, and of super-extra (fine filament) and fine-denier rayon with improved feel and covering power, helped competition with silk very materially, although continually decreasing silk prices in 1930 tended to offset these advantages. Perhaps most progress in rayon's replacement of a fiber is found in the case of cotton, although use of the latter remains at some 30 times the consumption of rayon. Staple or short-length fiber, which continues to forge strongly ahead, is now the only important synthetic competitor to wool, and here it is chiefly used combined with wool, because of its novelty appeal.



Estimated Production of Four Principal Synthetic Fibers in the United States

Inside its own field, rayon also finds competition of several sorts. Sulphite pulp, cotton linters, and shorter cotton fibers from the cotton seed-coat are all used as sources of cellulose, ordinarily in combination. Although pulp is cheaper, linters appears to give somewhat better properties to the finished product and hence accounts for something over 40 per cent of the cellulose used. Specially refined high-alpha-cellulose pulp made headway at one time, but later fell into disfavor. It now appears to be gaining again. Work to develop other cellulose sources, as for example, cornstalk cellulose, has been carried out, but with no present indication that any extensive change from pulp and linters is probable. So far as fibers other than viscose are concerned, linters has been and still is supreme. Probabilities are that it will remain so.

Competition in processes most concerns the chemical engineer. Of the four processes, it is estimated that the total installed daily capacity is 205 tons for viscose, 25 tons for acetate, 15 tons for cupra and 10 tons for nitro rayon. The chart reproduced here shows estimated annual distribution of rayon production by processes since 1924. Although viscose fiber now outstrips its nearest competitor by more than 9 to 1, it should not be overlooked that acetate is growing rapidly, having more than trebled in the last three years. This is accounted for both by increased capacity for the original producer, Celanese Corporation, and by the entry of Tubize-Chatillon, DuPont, and Viscose Company into the acetate field.

It is reported that Tennessee Eastman Corporation is developing an acetate process experimentally and probably will go into production somewhat later. Because of properties which are superior for certain purposes, acetate has always been able to maintain a price substantially above the other fibers, and for this reason is probably not a true competitor. As such, its market doubtless is limited, although synthetic fibers in general may expand indefinitely. Which fiber will be capable of such expansion cannot be predicted, but it will probably be a product not yet known. Rumors, as yet unsubstantiated, indicate that at least three superior and cheaper materials are now in process of development. Not only the rayon industry, but the consuming public also, is awaiting these results with much interest.

Plastics Use Moderate Decline

To Plan Ahead

AMONG its principal products and, therefore, major producers, the plastics industry experienced a deceleration from its pace of 1930 in sympathy with that of its primary outlets, mainly a "producers' demand" in such other young industries as the automobile, electrical, and radio. Most affected were the smaller companies, because of their lesser financial adaptability. The leaders, by other standards than 1929, had a really tolerable year, while new technical developments were only slightly affected by unfavorable marketing conditions. On the whole, as a new industry in the scheme of affairs, plastics manufacture may be said to have had a lull in its growth through temporary undernourishment, but will hasten to its ultimate stature all the more rapidly when markets regain a normal vitality. Curiously, the year's depression in plastics falls about half way between the 20 and 35 per cent each estimated for the chemical and general business.

Within itself the industry displays a remarkable combination of competition and opportunity. The former has resolved itself into a quiet struggle for satisfactory cheap products, on one hand, and a restless activity among primary chemical producers to offer cheaper, better raw materials, on the other. The complications and conflicting factors, of course, project a picture of amazing possibilities. Meanwhile some of the smaller plastics producers are suffering real distress, while chemical manufacturers at large are competing to introduce a plastics outlet into their technical balance sheet. Opportunity, again, is shown by the uninterrupted development of new products, on the basis of some special properties or uses, in face of the obvious fact that only a miracle can bring them within the price range of phenolic resins. But they perform various services closed to the latter, and material cost is not always the decisive factor.

Market competition among plastics falls further into two general phases: public appeal and technical suitability, normal stability being assumed from the outset. Color is a prime facet of public appeal, and the rational observer may find that it is extorting an altogether extravagant stress, which, in the long run, might better have been diverted to more lasting attainments. On the other hand, technical performance is demanded to the ultimate degree by such users as the telephone companies, and very few materials are then found to be generally suitable. Phenolic resin, cellulose acetate, impregnated cloth, and vulcanized fiber are all exploited for specific uses, but satisfying these, the less conspicuous but more permanent advantages become real assets. Before the different products are treated separately, it should also be emphasized that coating and impregnating materials, sheet wrapping, and even rayon are, strictly speaking and by their origin too, factors in the plastics industry. These are discussed elsewhere in this issue, but cannot be disregarded in a survey here.

Cellulose-base Plastics

Regenerated cellulose (or viscose), while the greatest quantity factor among all plastics, flourishes mainly by virtue of two products, thin wrapping and rayon. In both cases it has growing competitors, but since rayon is treated on a following page, the sheet material will be mentioned here in connection with the cellulose esters, nitrate and acetate, which have a wider list of applications. It is becoming timely to point out too that other esters of cellulose probably will be heard from in the future, depending on the availability of cheap, suitable organic acids.

Raw materials and other normal factors were less significant to the pyroxylin industry during 1930 than the effect of the automobile slump. Just when motor cars were adopting safety glass on a wide scale, and the public was well aware of its protective properties, the consumer's market and then, in consequence, the producer's market shrank disastrously. A year ago this was calculated to represent, potentially at least, 20,000,000 lb. of pyroxylin plastic sheeting, or about $25,000,000. Of course only a fraction of this hypothetical amount was lost during 1930, but it contributed greatly to an estimated 30 per cent total decline in the industry's business, leaving about 20,000,000 lb., against 30,000,000 lb. in 1929.

The safety-glass outlet for pyroxylin sheeting will recover, of course, whenever automobile sales reach normal. Meanwhile, producers have been constantly occupied by improvement of the material, both in manufacturing economies and in greater permanence during use. Safety glass has been only one of the newer fields of promise; phonographic records of solid plastic or impregnated sheets are already public to some extent, but not to the degree in which they excel the traditional shellac type. Fillers reduce the fire hazard, and only a few minor points yet await solution.

Films of various sorts again were the mainstay not only of pyroxylin plastics but of cellulose acetates too. The acetate is generally conceded to have an excellent future, even though its price is still rather high. The machined solid and sensitized film are not new to the trade, but the molding powder is only in its second year commercially, while thin wrapping from this material probably will be offered by several producers in the early future. The optimism with which it is attended, despite its price, arises from its special properties in addition to its limitless color range. For one thing, it is thermoplastic; i.e., mechanically workable under heat; for another, it preserves its high dielectric constant in spite of exposure to moisture; for a third, it transmits ultra-violet rays.

Replacement of cellulose nitrate has been the objective of acetate in many applications, and during 1930 satisfactory progress was made toward surmounting the various technical obstacles. Both safety glass and quality phonograph disks, therefore, probably will be shared by them soon, while molded goods and other trade ware, along with sensitized film, are already partly supplied by the acetate. As an outside coating, applied with solvents, its resistance to disintegration through light promise it extended application. For electrical insulation such coatings are being utilized commercially, because of the dielectric properties already mentioned. A similar use is served in the case where acetate filaments are wrapped closely over coils and then lightly sprayed with acetone to produce a continuous coating. The acetate sheet that is predicted to appear this year is intended to supplement the increasingly wide market that viscose sheet has opened. Its advantages appear to be greater impermeability and clarity, and the possibility of a seal by heating.

Hitherto all transparent wrapping sheet (excluding various papers) has been supplied by viscose. By varying its markets in 1930, the consumption was driven into a record year, despite adverse general conditions. Moisture-proof sheeting (coated) has increased especially, its main outlet being cigar and bakery wrapping. The material is supplied principally by one company, but another went into operation early in 1930 and expired patents probably

will attract others. The total production for 1930 is estimated to be well over 200,000,000 sq.yd. for all companies, a trebled output since 1927. Of course, this does not include other flourishing uses for regenerated cellulose, such as extruded sausage casings and artificial hair for clothing, which have won themselves firm markets.

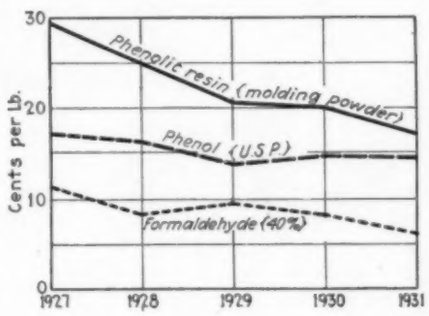
Phenolic Resins

The name "phenolic resin" is applied commercially to all similar compounds without regard for the true constituents, which are numerous and of varied origin, though similar structurally. Thus cresol, resorcinol, and indol are used parallel with phenol, while formaldehyde is sometimes replaced by furfural and other aldehydes. This suggests what may very well be the future of the industry: when some complex carbol such as diphenyl hydroxide or dihydroxide shows price and condensing advantages over phenol, it will open a whole new series of possibilities susceptible to side-group modifications and arrangements. And its production may be a mere opportunistic "byblow" of some other chemical operation.

In this group price is the prime element of competition, since a generally excellent product has long been achieved. During 1930 the tendency was downward to a base price of 23 to 20 cents per pound (black or brown molding powder), but the newly announced prices for 1931 begin at 17 to 19 cents. In addition, the long-whispered advent of phenolic resins in pastel shades has materialized—at the highly competitive price of under 50 cents per pound. Naturally the situation is grim to the small producers and at least challenging to the non-phenolic plastic producers.

Production declines did not affect all factors with equal severity. Compared with the peak in 1929, for which official figures were about 33,000,000 lb., although hidden production probably would have brought it to about 40,000,000 lb., the estimate is about 30,000,000 lb. for 1930, including resin for molding and in solution. But while only a 10 per cent decline was felt by one firm, for example, the average was greatly decreased by the field at large, which dropped close to 40 per cent of its production throughout the year. This is readily understandable when it is considered that each automobile uses about 1 lb. of laminating varnish, and that radio tube bases, another large outlet, not only declined sharply from normal anyway but were greatly overproduced in 1929.

The raw materials situation is somewhat more difficult to evaluate for 1930, earlier production trends and prices being shown in the table and graph. Formaldehyde reached new low levels in price and any amount is available from synthetic producers. The percentage of resin consumption is not evident from its production figure, although in the case of phenol this might be indicative. But in the face of a large overstock of phenol on the part of one resin manufacturer during 1930, an unexpected and large export demand arose from Italy early in the year, which, though it helped to stabilize the price, allows of no immediate deductions on the resin field. It is certain, however, that the essential raw materials can now be produced domestically at will, without the necessity of sudden imports as in 1929; and no advances in price appear to be at all likely. It is estimated that the plastics consumption (principally phenolic) of wood flour declined in 1930 to 5,000 tons, from 7,000-8,000 tons in 1929.



As far as technical improvements go, the year seems to have been spent in very foresighted development work which will make the producers less dependent on general "prosperity" in 1931. Large panels have been made and applied to interior construction, although the much-heralded furniture development has been definitely postponed. The phenolic resin has also passed trying tests for use in telephone hand sets and should greatly profit from this achievement. The pastel color announcement has already been mentioned; but the fading characteristics of phenolic resins have been more generally combated and greater uniformity is now achieved by one producer through larger-quantity batches and blends. A so-called core resin, used in foundries as binder in sand cores, entered the market in 1930, offering greatly reduced baking time and elimination of fumes and hazards as outstanding advantages. It is generally known that phenolic resins are becoming more firmly allied than ever with such applications as tube caps, electrical devices and mechanical parts.

Resin to the amount of about 15,000,000 lb. was consumed in 1930 for use as coating. Originally resin coatings were heat-cured, but after pyroxylin lacquer achieved its success, it was found that the rosin ingredient could be displaced by synthetic resin. Then a quick-drying varnish was made, incorporating principally resin, rosin, and solvent. In 1930, however, a new air-drying resin varnish was announced whose high resin content gave a much improved coating, and is expected to become a considerable factor in the future. Electric refrigeration has been in part responsible for the development of an odorless laminating varnish, also announced during 1930.

An individual development of unusual interest was the commercial manufacture of a quick-curing resin, used primarily in the form of cheap phonograph disks. This involves the use of a polyhydroxyl carbol in the place of phenol, and the sensitive reaction is so well controlled commercially that it became an economic success in a very short time. Although the lucrative field of flexible disks was first exploited, many other uses stand before. Among these may be mentioned printing matrixes, cap liners for food jars, weatherproof coatings, and thin, flexible electric insulation of laminated sheets. This case may be cited as an instance in which the advent of a new product has nourished the manufacture of a raw material into altogether new proportions.

Urea-Formaldehyde Resins

Among the conspicuous commercial developments during the past year was the intensive sale of urea-formaldehyde plastics, especially table and other household ware. In the face of a generally adverse market, these products were strikingly introduced to the public by a marketing subsidiary of the leading producer on the basis of their color.

As in so many "competitive" cases, this type finds applications without directly displacing any others. Its wide possibilities in non-fading coloration, non-flammability, and light weight are its principal assets. The main detriment in the past, crazing (due probably to moisture influences) has been eliminated at least in the thinner forms; meanwhile heavier prices are not fabricated pending further technical advances. The main applications therefore are, primarily, tableware and more recently, clock cases, meter cases, cosmetic boxes, and similar objects.

The stable price of one producer's molding powder is about 60 cents per pound, irrespective of color. This is not dependent on raw material costs (urea, thio-urea, formaldehyde) so much as on manufacturing operations, where cleanliness plays a major part. The latter holds true in the polymerizing-molding plants too, where a technique similar to that used for phenolic resins

Production Trends in Synthetic Resin Industry, 1927-1929

All Figures in Lb.—Source: U. S. *Census of Dyes*, 1929

	Phenolic Resins	Phenol		Formaldehyde	Hexamethylene-tetramine	
	Production	Production	Imports	Production	Production	Imports
1927.....	13,452,230	8,041,082	500	29,920,072	1,315,213	3,417
1928.....	20,411,465	10,227,489	1,653	38,717,732	1,661,645	5,898
1929.....	33,036,490	24,177,618	443,385	51,786,422	2,368,020	5,562

is segregated and modified to insure an absolute freedom from dust and dirt.

Although exact figures are not available, the production for 1930 was somewhere in the neighborhood of 50,000-60,000 lb., and in 1931 will be about 50 per cent higher, assuming average general conditions. Synthetic formaldehyde is used and the urea compounds are obtained from both cyanamide and byproduct coke plants.

Other Synthetic Resins

Emerging from the purely development stage in 1930, the polymerized styrol resins are now in small-scale commercial production and have been introduced for trial wherever they showed promise. This exploration of outlets was accompanied by improvements in the manufacturing operation, which is to be expanded in additional facilities now under construction. By this consequently improved procedure the price undoubtedly will be lowered from its present rather high level.

Its derivation from so simple a compound as ethyl benzene, no less than its tested properties, makes the styrol plastic a singularly promising one. Like some of the other plastics, its dielectric properties are outstanding, but at radio frequencies it has been found to excel any other material except quartz. It might be added at this time that it seems eligible as a varnish base and as laminated glass ingredient because it is not affected by moisture or weak reagents and offers any color possibilities from clear transparency onward.

Vinyl compounds, although not yet reported in commercial production, were the subject of further development and sample-lot sales in 1930. This year they are expected to make considerably more progress. Here again one is dealing with a polymerized resin (chloride, acetate), starting from ethylene in an American, and from acetylene in a Canadian process. Apparently stress is being laid just now on their use as dissolved coatings, rather than on molded solids. An interesting parallel, incidentally, exists between the structure and properties of the vinyl resins and natural rubber.

Glycerol-phthalic anhydride resins again have played a not very tangible part in the year's developments. The company primarily concerned has long been a user and molder of other plastics and, having licensed the use of its own as molding compound and lacquer, seems to be employing it mainly for metal coatings, where its adhesive properties recommend it. It has appeared publicly in such forms as pencil barrels and automobile undercoatings.

Casein-formaldehyde compounds do not appear to have strengthened their position in the past year. Their advantage of brilliant coloration and light weight are still offset by their susceptibility to moisture, imperfect fabrication methods, and relatively high price. Though these may all perhaps be overcome, it will need an altogether different picture in the dairy industry supplying casein to bring the raw material within competing range of the phenolic resins.

Asphalt-base plastics are often disregarded because of the mechanical weakness of the old cold-molded type, but they deserve mention here for their low price and improved properties as hot-mixed compounds (without solvents). Commercially they do go into such objects as battery and radio cases, and it is possible to electroplate directly on them. At about 2 cents per pound they are recommended where less exigent conditions do not require more expensive materials, for they acquire no direct polish in the mold, remain thermoplastic (subject to cold flow), and have a comparatively low ultimate strength. But they are far from the old electric plugs that broke down under a severe gaze.

Fuel Competition Intensified During 1930

Editorial Staff Interpretation

COAL - PRODUCTS manufacture during 1930 appears to have been one of the most stable parts of the fuel industry. This situation is rather surprising, because for many years it has been the custom to assume that the coke industry would speed up or decline in activity with the steel business. As a matter of fact, the manufacture of coal products is today almost as much responsive to city-gas needs as to the coke requirements of the metallurgical business.

Production of byproduct coke and of other coal products at byproduct-coke works in the United States during 1930 was at the rate of about 85 per cent of the record-making rate of 1929. Coke production of approximately 45,500,000 net tons exceeded the byproduct-coke output of any preceding year except 1928 and 1929. The output of byproducts was approximately in proportion.

Beehive-coke-oven operation fell to the lowest level recorded for any year since the beginning of the reporting of official statistics in 1880. The output of approximately 2,750,000 tons of beehive coke was barely half of that in the last slump year, 1921. It is evident, therefore, that the beehive-coke industry is continuing more and more to serve as a balance wheel in supply, and when coke demand is low this branch of the industry shrinks or, as in 1930, practically disappears from the industrial map. Fortunately, this shrinkage in the beehive division of the industry has no effect on the output of other products, such as tar, gas, light oil, or ammonia.

Census figures for the combined coke and byproduct business of the United States for the calendar year 1929 show that the combined industries have shrunk materially in number of establishments, number of wage earners, and total wages paid. The value added by manufacture and the total value of products, however, have increased since the last preceding census year, 1927. Apparently the decline in number of establishments and in number of wage earners reflects the tendency toward larger establishments with more highly mechanized equipment. That these industries should, despite the retention of a large number of small works in the smaller communities, have been able to advance the value of production by over 3 per cent in two years, while the total wage expenditure declined by 8 per cent, shows that the industry is making an intensive effort to better its internal economic situation in order to meet the

Marketed Production of Liquefied Petroleum Gases

(Data from U. S. Bureau of Mines)

Year	Gallons	Year	Gallons
1922	222,641	1926	465,085
1923	276,863	1927	1,091,005
1924	376,488	1928	4,522,899
1925	403,674	1929	9,925,698

Coke and Gas Industries

(Data from Census of Manufactures, 1929)

Number of establishments	859
Wage earners, not including salaried employees	63,738
Wages paid	$94,000,000
Cost of purchased fuel, electricity, and materials	$472,000,000
Total value of products	$928,000,000
Value added by manufacture	$456,000,000

Coke and Coke Byproducts in 1930

(Production estimates for 1930 by *Chem. & Met.*, not including gas-retort plants)

	Short Tons
Coke made:	
Byproduct ovens	45,500,000
Beehive ovens	2,750,000
Total	48,250,000
Ratio to previous years operations:	**Per Cent**
Byproduct ovens	85.2
Beehive ovens	42.5
Total	80.5
Byproducts made:	
Gas, total, billion cubic feet	720
Light oil, crude, million gallons	170
Tar, million gallons	580
Ammonia, total calculated as sulphate, tons	725,000

intensive competition of other fuel supplies.

The city-gas requirements of the country for many purposes have continued to advance rapidly, and, despite the industrial difficulties of the nation in 1930, the actual gas sales by manufactured-gas companies of America increased a trifle, apparently less than 1 per cent, over the preceding year. The total sales of natural gas, including industrial and commercial operations, however, were a trifle less, about 1 per cent below 1929. In the aggregate, therefore, the public-utility gas business marked time in its effort to monopolize city-fuel supply.

The total production of natural gas probably increased in 1930 over the total production in the preceding year, largely because of the exploitation of certain new fields in California and in the Panhandle of Texas. Extensive pipe-line construction was undertaken for the transmission of these gas supplies to municipal consuming centers, at distances ranging up to a thousand miles from the point of production. Despite the undertaking of several thousand miles of pipe-line construction during the year, there was not a sufficient number of the lines completed to prevent a great deal of wastage of gas in the producing areas. Apparently with the completion of the lines already definitely under construction or projected, natural gas will be in position to furnish either base-load or total city supply in substantially all of the states. Exceptions are a narrow region running eastward from Michigan to Maine and southward along the Atlantic Coast from Maine into the Carolinas, with some gaps in the unreached area at points like Detroit, Baltimore, and Washington, toward which projected lines are reaching.

In the Far West, the tremendous gas supply of the Kettleman Hills region is threatening all other fuels. In some areas about San Francisco the gas supply is entering directly into competition with fuel oil for boiler firing. Such competition, however, is not likely to result in most Eastern areas served by new natural-gas lines. Exceptions are possibly those nearest to the Panhandle of Texas and to northern Louisiana, from which it appears feasible to take gas for reasonable distances in such quantities and at such low cost that it may successfully enter the boiler-firing competition. A more complete discussion of the natural-gas competition has already been presented in *Chem. & Met.* (see page 673, November, 1930).

The extent to which natural-gas development and the corollary fuel-oil competition may affect the use of solid fuels is difficult to estimate. It appears safe to forecast a large and steady increase in the gas supply, certainly up to the point of doubling the present rate of use. As a consequence, it is not too much to expect that at least 20 per cent of the energy supply of the country will be furnished by gaseous fuels within the next five or ten years. These results are already being felt by both bituminous and anthracite divisions of the coal industry. They are causing great concern to railroad executives, who visualize a shrinkage in the transportation requirements of the fuel industry, since gas moves through pipe lines and not, like coal, in freight cars. Some more optimistic forecasters suggest that as much as 30 per cent of the energy supply of America will be furnished by gaseous fuel not later than 1940. If that forecast be fulfilled, then we are entering into a decade of fundamental readjustment in the fuel business.

Some have thought that the invasion of natural gas into the public-utility business was likely to spell the ruin of the coke-oven and coal-products industry. Fortunately, this does not appear to be a probable result. There may be, and probably will be, a slowing up in the rate of erection of new coke ovens. As has been the case during the past decade, the rate of expansion probably will depend more on the rate at which the industry is able to market coke for household purposes than on any other single factor. Naturally, with the expansion of the gas supply for house heating, with the decided trend toward oil heating, and with the low prevailing prices for coal, which promise to continue for some time, the coke man does not have an easy task in expanding his household fuel markets. However, there does not appear to be any decided shrinkage in these markets. Nor is there any evidence that natural gas for city supply is going to close up coke works previously furnishing gas for public-utility distribution. The two fuels are being mixed in many cases, and it appears that the intimate corporate relations between coke and utility companies is going to maintain the present coke industry in a fairly satisfactory situation, even though it may not grow as fast as it would have were natural gas not so aggressive a competitor.

THE market for other coal products —light oil, ammonia, and tar—has continued in about the situation described a year ago in these pages. Tar-products manufacturers have suffered somewhat less than the makers of other construction materials. This has resulted from the fact that their products are used largely on highways and for heavy and engineering construction; not in small house building.

The market for ammonia in all its various forms has, of course, been sadly disturbed. A full discussion of the nitrogen situation is found elsewhere in this issue. The outlet for light oil continues to be essentially supplying motor benzol for blending of automotive fuels. This demand apparently has not shrunk, although the necessity for benzol in fuel blends is less than a few years ago. This situation is the result both of the development of anti-knock materials, particularly ethyl fluid, and petroleum-refining methods which leave many of the anti-knock constituents in the gasoline that were formerly eliminated in a desire to meet specifications that were both unnecessary and uneconomic. It appears that the market for motor benzol will continue more or less indefinitely to absorb all of the surplus of the light-oil production, above that relatively limited quantity needed in the chemical industry for the making of refined benzol, toluol, and solvent naphtha.

Byproducts Obtained From Coke-Oven Operations in 1929

Product	Unit	Production	Sales		
			Quantity	Value	
				Total	Average
Tar	Gal.	680,864,366	333,557,501	$16,982,406	$0.051
Ammonia:					
Sulphate	Lb.	1,488,314,447	1,433,465,592	25,861,479	.018
Ammonia liquor (NH_3 content)	Lb.	56,028,347	55,470,678	2,820,802	.051
		.....	.....	$28,682,281	.....
Sulphate equivalent of all forms	Lb.	1,712,427,835	1,655,348,304	.....	.....
Gas:					
Used under boilers, etc	M. cu.ft.	a843,148,089	18,506,502	1,282,327	.069
Used in steel or affiliated plants	M. cu.ft.		302,165,465	31,901,504	.106
Distributed through city mains	M. cu.ft.		160,560,921	46,994,632	.293
Sold for industrial use	M. cu.ft.		26,357,691	4,125,807	.157
			507,590,579	$84,304,270	$0.166
Light oil and derivatives:					
Crude light oil	Gal.	b200,594,027	11,090,709	1,374,527	0.124
Benzol, crude and refined	Gal.	24,944,531	24,558,745	5,169,743	.211
Motor benzol	Gal.	105,923,762	100,807,852	16,063,285	.159
Toluol, crude and refined	Gal.	18,343,295	17,064,206	6,580,176	.386
Solvent naphtha	Gal.	7,131,111	6,581,047	1,591,333	.242
Other light oil products	Gal.	6,675,386	1,877,176	124,948	.067
		c163,018,085	161,979,735	$30,904,012	$0.191
Naphthalene, crude and refined	Lb.	19,761,382	19,659,367	320,272	0.016
Creosote oil	Gal.	26,730,126	23,938,431	2,296,862	.096
Phenol (crude)	Gal.	84,683	78,869	28,347	.359
Pitch of tar	Net tons	88,158	5,599	27,273	4.871
Other productsd	.....	.....	.....	129,848	.....
Value of all byproducts sold	.....	.....	.....	e$163,675,571	.....

(a) Includes gas wasted and gas used for heating retorts. (b) Refined on the premises to make the derived products shown, 194,882,679 gal. (c) Total gallons of derived products. (d) Brimstone, carbolate, textile covering, smoke compound, sodium prussiate, sulphur and tar paint. (e) Exclusive of the value of breeze production.

Methanol Affected by New Denaturing Formulas

By H. W. Rinehart
Du Pont Ammonia Corporation
Wilmington, Del.

IN THE short space of a year, two important and far-reaching developments have occurred in the methanol industry. The first of these has been the invasion by methanol of the anti-freeze field, which has provided the largest single outlet for ethyl alcohol. Such a development, made possible by an astonishing increase in the production of synthetic methanol, passes on to the consumer the benefits and economies derived from the discoveries which modern methods of industrial research are making possible. This is indicated by the price trend for methanol over the last nine years. Prior to 1928, the lowest average annual price of methanol was 70 cents per gallon in 1925 and 1927 and the highest was $1.25 in 1921; with the inception of production of synthetic methanol in 1928 the price dropped to 52 cents and in 1930 still further to 40½ cents. Such a decrease in price has made possible the introduction of methanol into the anti-freeze field during the winter 1930-31 in quantities which it is estimated will reach a total of approximately 4,000,000 gal. for the season.

Less favorable was the effect on the wood producers of methanol of the announcement made in November by the Bureau of Industrial Alcohol that over the remainder of 1930 only 2 per cent of wood alcohol, instead of the usual 4 per cent, would be required as a denaturant for completely denatured alcohol formula C.D. 5. Still more devastating to the wood alcohol industry was the Bureau's later announcement that, as of Jan. 1, 1931, completely denatured alcohol formula C.D. 1 would be discontinued and completely denatured alcohol formula C.D. 5 would require no wood alcohol. This use of methanol produced by the wood distillers has in recent years provided a market for which there has been no competition. Were it not for the new market for methanol as an anti-freeze, the wood producers' market for this product would be very seriously threatened. As it is, it seems probable that some of the producers whose operating costs are high will discontinue operation during 1931.

The accompanying table shows production and stocks of crude and refined methanol from wood operations and also, for the first time, gives government figures on the production of synthetic methanol. It is estimated that during 1930 about 7,000,000 gal. of refined methanol will have been produced synthetically and 3,500,000 gal. of refined methanol by the wood distillers. During 1931 capacity for the synthetic production of upward of 10,000,000 gal. of methanol will be available.

The increase in stocks of synthetic methanol during 1930, as reported by the government figures, is due to increased production of the manufacturers to meet the seasonal demands of the anti-freeze market.

Methanol

Refined

	From Wood Distillation			Synthetic		
1930	Production Gal.	Shipments Gal.	Stocks, End of Month Gal.	Production Gal.	Shipments Gal.	Stocks, End of Mo. Gal.
Jan.	248,723	425,071	695,155	464,423	411,892	572,638
Feb.	394,647	451,173	638,258	445,418	387,694	630,362
March	398,476	522,153	514,705	483,274	599,738	657,173
April	424,295	530,584	408,764	506,936	389,145	795,435
May	373,780	407,940	374,803	576,973	420,796	951,611
June	376,205	441,870	309,587	555,620	298,384	1,208,847
July	265,509	356,274	218,532	405,375	259,971	1,354,252
Aug.	275,712	310,215	184,107	427,832	475,458	1,306,625
Sept.	201,663	365,927	20,346	488,063	622,094	1,172,595
Total (9 mos.)	2,959,010	3,811,207	.....	4,353,914	3,865,172	.....
Corresponding month of previous years						
Sept., 1927	441,771	506,914	382,876	.....	.....	.....
Sept., 1928	355,353	415,340	300,478	.....	.....	.....
Sept., 1929	432,094	598,551	729,932	.....	.....	.....
Total for previous 9 month periods						
1927	3,725,198	3,892,568	.....	.....	.....	.....
1928	4,290,945	4,391,365	.....	.....	.....	.....
1929	3,933,173	4,433,016	.....	.....	.....	.....

Domestic Production of Sodium Compounds, 1927-1929

	1929	1927
Total value	$132,996,671	$113,880,497
Acetate:		
Pounds	592,253	1,854,588
Value	$32,846	$80,553
Bichromate and chromate:		
Tons	37,401	31,462
Value	$4,891,469	$3,780,435
Borate (borax):		
Tons	92,250	64,864
Value	$3,279,641	$5,079,278
Carbonates:		
Bicarbonate, refined—		
Tons	140,234	121,449
Value	$4,062,074	$3,647,446
Sal soda—		
Tons	62,062	55,220
Value	$1,581,153	$1,370,811
Soda ash—		
Total production, tons	2,682,216	2,037,808
Made and consumed, tons	868,360	571,429
For sale—		
Tons	1,813,856	1,466,379
Value	$34,648,657	$29,939,291
Production, by process—		
Ammonia-soda—		
Total production, tons	2,586,304	1,974,157
Made and consumed, tons	868,360	571,429
For sale—		
Tons	1,717,944	1,402,728
Value	$32,540,935	$28,645,404
Natural and electrolytic soda—		
Tons	95,912	63,651
Value	$2,107,722	$1,293,887
Modified sodas—		
Tons	59,618	53,866
Value	$1,792,356	$1,827,521
Caustic:		
Hydroxide—		
Total production, tons*	758,800	†573,417
Made and consumed, tons	38,595	26,112
For sale—		
Tons	720,205	†547,305
Value	$35,801,988	$29,193,003
Production, by process—		
Electrolytic, tons	233,815	†186,182
Lime-soda, tons	524,985	†387,235
Repacked caustic (purchased in bulk)—		
Tons	17,474	21,104
Value	$3,611,573	$4,128,433
Hypochlorite:		
Tons	26,772	†14,697
Value	$2,015,817	$1,140,746
Phosphates:		
Tribasic—		
Tons	82,045	63,531
Value	$5,008,815	$4,524,595
Monobasic, dibasic, and not specified—		
Tons	64,134	32,950
Value	$3,955,723	$2,460,656
Silicate (basis 40 deg.):		
Tons	591,345	504,518
Value	$7,195,747	$6,826,099
Silicofluoride:		
Tons	2,278	1,646
Value	$228,094	$191,687
Sulphates:		
Niter cake (bisulphate)—		
Total production, tons	91,617	153,615
Made and consumed, tons	8,304	33,109
For sale—		
Tons	83,313	120,506
Value	$1,031,836	$625,049
Salt cake—		
Total production, tons	217,628	208,565
Made and consumed, tons	33,159	33,573
For sale—		
Tons	184,469	174,992
Value	$2,362,243	$2,786,818
Glauber's salt—		
Tons	59,021	53,420
Value	$1,066,909	$1,081,980
Refined anhydrous—		
Tons	4,454	2,688
Value	$174,513	$119,111
Hyposulphite (thiosulphate)—		
Tons	25,021	23,574
Value	$906,369	$992,865
Sulphide:		
Tons	31,918	38,446
Value	$1,340,700	$1,691,609
Sulphite:		
Tons	5,970	5,030
Value	$462,072	$399,529
Other sodium compounds, Value	$16,343,214	$11,096,729

*Not including caustic soda made and consumed in the wood-pulp and textile industries.
†Revised

Ethyl Alcohol Production On Reduced Scale

FOR THE fiscal year ended June 30, 1930, production of alcohol at industrial alcohol plants was reported at 191,859,342 proof gallons. This represents a decline from the output of the preceding fiscal year. In the calendar year 1929, production was 206,662,000 proof gallons, of which 195,470,000 proof gallons was withdrawn for denaturing. In the first ten months of 1930, production was 128,522,000 proof gallons, with withdrawals of 117,141,000 proof gallons. Comparing the ten months' periods, it is found that production in 1930 was about 25 per cent below that of 1929, with a similar drop in the quantity withdrawn for denaturing.

The decline in demand for alcohol is explained partly by the slower position of consuming industries, partly by improved control, which largely eliminated diversion of denatured alcohol into illegitimate channels, and partly by increased competition from other materials. An instance of the latter is exhibited in the invasion of the anti-freeze trade by methanol. As an instance of checking diversion, reference is made in the annual report of the Commissioner of Prohibition to the modification of Formula No. 44A, which has practically eliminated the diversion of lacquer thinners and solvents.

THE most important development in connection with denatured alcohol was the change made in the use of denaturants. The old formula, with the exception of a temporary modification in December, prescribed the use of 4 per cent of natural methanol and three-quarters of one per cent of aldehol. Effective Jan. 1, 1931, this formula was changed so that 1 per cent of alcotate was substituted for the methanol, and the aldehol content was increased to 1 per cent.

Alcotate is a derivative obtained from California petroleum in the cracking process and is extremely obnoxious both in odor and taste. It is believed that the new denaturant cannot be removed from industrial alcohol by any chemical process, thus preventing the use of alcohol so denatured as a beverage.

After considerable research, a petroleum distillate known as calol ethatate was required as a denaturant for ethyl acetate. This denaturant in conjunction with restrictive measures relative to the sale and distribution of ethyl acetate has practically eliminated the diversion of this product for illegal purposes. After the modification of specially denatured alcohol Formula No. 44-A, which eliminated the diversion of lacquer thinners and solvents, some of the bootleggers turned to ethyl acetate, which is produced from specially denatured alcohol, for their source of liquor. The adoption of calol ethatate as a denaturant for ethyl acetate has closed this source of illegal liquor.

BECAUSE of the letdown in buying activity production allotments for 1931 have attracted less interest than usual. It is expected that 170,000,000 proof gallons will be repeated but actual output undoubtedly will be influenced by the receptive capacity of the market. Producing costs for the coming year should be lower than was the case in 1930. This is based on the belief that blackstrap molasses, which is the most important raw material in alcohol manufacture, will sell at levels below the average maintained in 1930.

During the last year a permanent permit was granted to a large chemical corporation for the production of synthetic ethyl alcohol from ethylene gas on a commercial scale. The company, under this permit, has already produced a large quantity of ethyl alcohol and the Bureau of Prohibition reports that from its capacity it will take rank with some of the larger producers of alcohol now operating. The ethyl alcohol produced is sufficiently pure to be used in practically 90 per cent of the preparations and processes now using ethyl alcohol produced by the fermentation of blackstrap molasses or grain. If necessary, it could be sufficiently purified to be used in any preparations or processes now using alcohol produced by fermentation.

In view of the importance of blackstrap molasses as a raw material for the manufacture of alcohol, considerable interest attaches to the proposal to include this material in the option market of the New York Coffee & Sugar Exchange. The proposal was sponsored by alcohol producers and was favorably received by the exchange. It is expected that definite action will be taken next February. Trading in futures will give the alcohol trade a hedging market and should reduce the necessity for placing long-term contracts by alcohol manufacturers.

Alcohol Produced at Industrial Alcohol Plants and Withdrawals for Denaturing

Fiscal Years 1920-1930

Fiscal Year	Alcohol Produced Proof Gal.	Ethyl Alcohol Withdrawn for Denaturation Proof Gal.	Denatured Alcohol Produced — Completely Wine Gal.	Denatured Alcohol Produced — Specially Wine Gal.	Denatured Alcohol Produced — Total Wine Gal.
1920	18,933,511.02	45,640,948.6	13,528,402.99	15,307,947.18	28,836,350.17
1921	85,068,776.33	38,812,138.7	12,392,595.02	9,996,229.90	22,388,824.92
1922	79,906,101.50	59,549,919.6	16,193,523.60	17,152,224.31	33,345,747.91
1923	122,402,849.81	105,819,404.9	27,128,229.54	30,436,913.14	57,565,142.68
1924	135,897,725.83	121,576,196.1	34,602,003.72	33,085,292.04	67,687,295.76
1925	166,165,517.81	148,970,220.9	46,983,969.88	34,824,303.28	81,808,273.16
1926	202,271,670.32	191,670,107.2	65,881,442.43	39,494,443.80	105,375,886.23
1927	184,323,016.97	170,633,436.7	56,093,748.16	39,354,928.48	95,448,676.64
1928	169,149,904.83	159,689,378.2	46,966,601.28	45,451,424.28	92,418,025.56
1929	200,832,051.08	182,778,966.1	52,405,451.92	54,555,006.15	106,960,458.07
1930	191,859,342.42	181,601,420.3	58,141,740.88	47,645,796.84	105,787,537.72

Products Manufactured With Specially Denatured Alcohol

Year ended June 30, 1930

Products	Denatured Alcohol Used Wine Gal.
Lacquer, thinners, and solvents	12,583,943
Nitrocellulose	10,461,860
Vinegar	9,572,201
Ethyl acetate	7,173,660
Chemicals and food products	6,925,890
Pyroxylin and plastics	6,436,296
Shellac, paints, varnishes	4,537,209
Rayon	3,524,682
Drugs and medicines	3,522,171
Petroleum oils	2,029,601
Resin materials	1,974,647
Ether	1,502,949
Toilet preparations	1,486,623
Toilet water	1,453,231
Hair tonics	1,412,197
Tobacco and solutions	1,258,105
Photographic supplies	1,136,765
Liniments and lotions	1,113,293
Bathing alcohol	1,071,776
Leather and solutions	844,799
Antiseptic solutions	824,664
Perfumes	739,336
Solvents	632,434
Dyes and intermediates	593,676
Ethylene	557,589
Other manufactures	1,436,856
Total	84,806,453

Materials Used in Alcohol Production

Year ended June 30, 1930

Corn, lb.	547,664,198
Rye, lb.	763,699
Malt, lb.	19,686,467
Other materials, lb.	2,185,355
Hydrol acids, lb.	65,524,269
Liquids containing one-half of 1 per cent or more of alcohol, gal.	21,601,391
Molasses, gal.	234,502,783

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Production Alums and Other Aluminum Compounds, 1927-1929

	1929	1927
Aggregate value	$16,153,917	$13,563,095
Alums, total value	$9,603,139	$9,524,677
Aluminum sulphate (concentrated alum)—		
Tons	347,089	314,018
Value	$8,178,003	$8,012,626
Ammonia alum—		
Tons	5,270	5,411
Value	$286,772	$316,220
Soda alum—		
Tons	17,252	19,454
Value	$923,718	$1,044,196
Potash and chrome alums—		
Tons	3,699	2,291
Value	$214,646	$151,635
Aluminous abrasives:		
Tons	33,226	19,782
Value	$3,446,116	$1,970,000
Aluminum chloride:		
Tons	*3,080	*2,872
Value	*$225,184	*$161,613
Aluminum stearate:		
Tons	1,066	801
Value	$440,180	$322,516
Other aluminum compounds, Value	$2,439,298	$1,584,289

*Production for sale. Total production of aluminum chloride, as reported by the Bureau of Mines, was, for 1929, 16,551 tons, valued at $1,600,826; for 1927, 17,130 tons, valued at $4,054,080.

Smaller Exports of Turpentine And Rosin

WHILE there was a marked increase in consumption of rosin and turpentine in industry in 1929, the record for 1930 was not so favorable, despite the relatively lower prices which prevailed. In 1929, industrial consumption of rosin amounted to 1,104,771 bbl., and consumption of turpentine was 5,622,695 gal., representing gains of 16 per cent and 6 per cent, respectively, over the totals for 1928. Data are not available for industrial consumption in 1930, but it is certain that many of the consuming industries reduced their requirements and that total consumption of this kind fell materially below the level reached in the preceding year. Mineral oil thinners offer considerable competition to turpentine, as may be seen from the fact that sales of the latter in 1928 were reported at 59,168,760 gal. Low prices for naphthas affected the sale of turpentine in the last year, but in general the movement of naval stores was more directly influenced by the slower position of consuming industries.

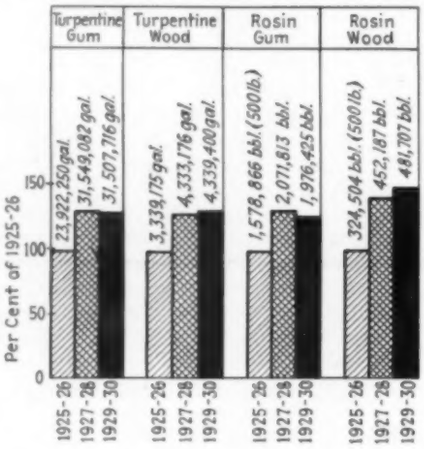
Over a period of years, export trade has accounted for approximately one-half domestic production of turpentine and rosin. In the last twelve months export buying was less active and a loss of nearly 10 per cent in the case of rosin and nearly 13 per cent in the case of turpentine was shown in comparison with export shipments in 1929.

Domestic production of wood rosin and turpentine was on an expanded scale last year, but in the latter part of the year producers curtailed outputs, in order to prevent large accumulations of stocks in producers' hands. Operations showed, however, that this branch of the industry was becoming more important and was able to speed up production whenever consuming demand warranted.

THAT competition from other materials has held in check, the growth of the naval stores industry is shown by the action taken at a conference during the convention of the National Paint, Oil, and Varnish Association in October. A committee was appointed to work along lines suggested by the conference which agreed: "That the urgency of the present situation demands immediate action on a definite program of an intensive educational and advertising campaign, directed primarily to the public at large and emphasizing the superlative merits of turpentine, not alone in the manufacture of paint and varnishes but as a thinner of paints and varnishes and for many other important manufacturing and household uses.

"It was generally recognized as essential that no time be lost in crystallizing the opinion of the industry along these lines, to stay the ever-increasing disintegration that is now taking place because of the apathy of producer and consumer alike as to the merits of turpentine.

"It was also the consensus of the meeting that the efforts of the industry must be directed toward the adoption of modern and better methods of production and merchandising."



Production of Turpentine and Rosin

Production From Crude Gum Crop Years Ended March 31, 1928 and 1930

Crop Year Ended March 31, 1930		Crop Year Ended March 31, 1928	
Turpentine, Gal.	Rosin, Bbl. 500 Lb.	Turpentine, Gal.	Rosin, Bbl. 500 Lb.
31,507,716	1,976,425	31,549,082	2,071,813

Production From Wood Distillation Calendar Years 1927 and 1929

—Calendar Year 1929—		—Calendar Year 1927—	
Turpentine, Gal.	Rosin, Bbl. 500 Lb.	Turpentine, Gal.	Rosin, Bbl. 500 Lb.
4,329,727	478,555	4,333,176	452,187

Fertilizer Sale About On Par With 1929

ACCORDING to figures compiled by the National Fertilizer Association, indicated sales in the 16 states where the tag system is used amounted to 5,832,473 short tons in 1930, compared with sales of 5,857,095 short tons for 1929.

For the calendar year 1930 the sales in the 16 tag sale states were 99.6 per cent of those for 1929, and 99.7 per cent of those for 1928. The sales for the 13 Southern states for 1930 were 100.9 per cent of those for 1929 and 99.6 per cent of those for 1928. The sales for the three states, Indiana, Illinois, and Kansas, combined were 78.3 per cent of those for 1929, and 103 per cent of those for 1928.

The 1930 sales for eight of the 13 Southern states exceeded those for 1929. The sales of three other Southern states averaged between 95 per cent and 100 per cent of those for 1929, and only in two Southern states did the 1930 sales fall below 76 per cent of the 1929 sales. The states were Texas (75.6 per cent) and Oklahoma (72.4 per cent). The annual sales for these two states are comparatively small.

Stocks of Turpentine and Rosin on Hand March 31, 1930 and 1928

	—March 31, 1930—		—March 31, 1928—	
	Turpentine, Gal.	Rosin, Bbl.	Turpentine, Gal.	Rosin, Bbl.
Total	6,349,189	608,578	*6,327,204	*608,734
Crude-gum stills	617,339	86,443	508,391	101,998
Industrial consumers	1,247,333	200,963	1,367,883	211,903
Wood-distillation plants	752,858	91,498	*543,114	*98,101
Ports and distributing points	3,731,659	229,674	3,907,816	196,732

*Not including data for stocks at destructive wood-distillation plants.

Factory Production and Consumption of Vegetable Oils

	—Domestic Production—			—Factory Consumption—		
	1928 1,000 Lb.	1929 1,000 Lb.	1930 1,000 Lb.[1]	1928 1,000 Lb.	1929 1,000 Lb.	1930 1,000 Lb.[2]
Cottonseed, crude	1,460,469	1,581,615	1,176,250	1,444,197	1,577,875	909,094
Cottonseed, refined	1,330,764	1,450,096	1,052,655	1,181,907	1,241,285	910,861
Peanut, crude	12,439	15,823	21,276	12,360	13,789	10,393
Peanut, refined	9,545	10,680	7,689	8,949	8,677	7,198
Coconut, crude	311,181	352,654	254,349	584,717	651,982	477,961
Coconut, refined	295,909	322,540	211,346	267,111	316,833	224,543
Corn, crude	124,327	133,679	84,737	130,533	151,552	92,466
Corn, refined	104,487	121,451	71,118	18,057	26,247	11,011
Soya bean, crude	4,716	11,046	7,360	15,457	20,828	13,407
Soya bean, refined	7,441	7,831	4,262	3,997	4,954	6,894
Olive, edible	1,438	1,003	809	2,081	2,067	1,935
Olive, inedible	13	29	.....	6,063	5,890	4,972
Sulphur oil	.....	.....	.....	34,846	38,804	30,037
Palm kernel, crude	.....	.....	379	45,389	58,309	38,990
Palm kernel, refined	16,607	14,566	10,800	16,753	13,840	10,693
Rapeseed	.....	.....	.....	15,169	13,548	8,898
Linseed	751,445	755,158	385,069	524,201	503,383	280,237
China wood	.....	.....	.....	95,093	97,823	69,657
Castor	64,521	76,060	36,819	27,484	28,831	14,611
Palm	.....	.....	.....	178,937	198,048	164,939
Other	4,987	12,304	14,478	10,559	15,263	21,065

[1]Figures represent 10 months for crude and refined cottonseed oil; 9 months for 1930 production of all other oils. [2]Figures represent first three-quarters of year.

Depression Fails to Retard Western Developments

By Paul D. V. Manning
Pacific Coast Editor
Chem. & Met.

WAS THERE a depression on the Pacific Coast in 1930? Yes; it came shortly after the middle of the year, but it has been a most unusual type of depression. It has seemed almost as if all manufacturers had started building new plants or enlarging existing units and were so busy that they could not find the time to spend as much money and play as much golf as before. Perhaps these Western manufacturers have begun to feel that before the depression is over, the Eastern population will all move out West and it is necessary, therefore, to prepare for a great increase in population. In any event, expansion has been carried out in the production facilities for practically every one of the process industries. The following sections comment briefly on some of the more important of these developments.

Nitrogen and Fertilizers—The Shell Chemical Company, affiliated with the Shell Oil Company, is pushing the construction of its large chemical plant on a 600-acre tract near Pittsburg, Calif. This plant will manufacture synthetic nitrogen products by the Mont Cenis process, as well as fertilizers and possibly certain solvents. The initial ammonia capacity is said to be 40 tons per day, with another 40 tons to be added shortly. Natural gas resources piped in will furnish fuel and probably will serve as a source of raw material for manufacturing operations.

In Los Angeles, a newly organized fertilizer company, the Agricultural Potassium Phosphate Company of California, has purchased the old San Pedro Harbor plant of the American Potash & Chemical Corporation and is manufacturing potassium phosphate fertilizer for domestic and export trade. The output for next year is expected to reach 40,000 tons. The company is stated to have purchased a phosphate mine near Paris, Idaho, and has also associated with it a sulphur producer.

Fixed nitrogen plants in the Northwest and California have operated to capacity during the past year. As previously reported in *Chem. & Met.*, the Consolidated Mining & Smelting Company has carried forward one of the major chemical engineering construction enterprises of recent years. The plant, located at Trail, B. C., is expected to produce ammonium sulphate, triple superphosphate and both mono- and di-ammonium phosphates. Recovery of sulphur dioxide from smelter fumes of the Trail plant is to furnish the sulphuric acid for which the present acid plant is being greatly enlarged. Synthetic ammonia and phosphoric acids are both to be produced by units under construction. The estimated cost of this large fertilizer plant is around $10,000,000 and production from the first completed units will begin in January of this year. Phosphate raw material will be drawn from Idaho deposits. This project is by far the most interesting of recent years. With plant operation, there undoubtedly will come a cessation of litigation over the smelter smoke damage, which has occupied the attention of an international commission for some time.

Petroleum and Natural Gas—Notable in petroleum refining is the newly constructed kerosene plant of the Union Oil Company. This plant, located at the Los Angeles refinery, is the country's largest kerosene plant. The Edeleanu process is used, treating 7,000 bbl. of kerosene stock per day.

The new California natural-gas conservation laws have materially helped the petroleum situation and have forced progress in the utilization of natural gas. There has been great activity in pipe-line work during 1930. Natural gas is also being sent through pipe lines formerly used for oil, and carloads of liquid butane are being shipped to remote Pacific Coast points, gasified and put into pipe lines for local consumption. The oil companies are also selling cylindered gas for use on farms. The consumption of gasoline in California alone rose to over a billion gallons in 1930. The total capital invested in oil production and refining equipment in the state now totals over one billion dollars. A start in disposal of petroleum coke has been made by the establishment of a Los Angeles plant for briquetting it.

In Utah, there has been an increase in the use of natural gas, which has lately been piped into the state. It is being tried out as a fuel for reverberatory furnaces at Garfield, Utah.

Borax—Although production figures are not at this time available, it seems likely that borax production has remained about equal to that of 1929, or will show a small increase, because of the activities of several of the smaller producers. Larger producers have maintained their production.

American Potash & Chemical Corporation, operating at Searles Lake, in California, has embarked on an expansion program which will ultimately add to this company's present capacity by about 50 per cent. This program, begun in 1930, may be completed during 1931. Just what effect this added production will have on the price of borax during the coming year is problematical, but it would seem that the price is not destined to drop greatly during the coming year unless producers get into a "borax war." The present price is low and, based on borax alone, it is not possible for any of the existing producers, with present methods, to make large profits. Most of the producers are turning to diversification of products to aid in insuring future activities.

Research on new uses of borax is progressing and results of this work together with the low price of this interesting alkali have had considerable effect on the soda ash industry.

Practically the entire production of the year has come from the salines of Searles Lake and the deposits of rasorite, both in California. There has been a small production from the brines of Owens Lake (California), but this operation is not regarded up to the present as strictly commercial. The minerals, ulexite and colemanite, still furnish opportunity for research on new uses as very cheap sources of boron compounds, but as yet there has been evidenced little in the way of a definite future from this angle.

Natural Soda—As the fixed nitrogen industry has developed, there has been an unusual opportunity for producing salt cake from natural sources. A large plant was projected for this purpose in Canada. In the western United States, exploitation of several natural sulphate deposits has begun, notably in Wyoming and Nevada. There are still opportunities in eastern Washington and in California, but several organizations which six months to a year ago were active in the consideration of these projects are now disposed to wait for a time to ascertain what effect the increase in natural production now under way will have upon the price. The market price of salt cake is so low that the establishment of new plants at new points for the production of sulphate alone is venturesome. There are certain basic costs that cannot easily be lowered and these plus the required rail freight charge on the product from the usually desert location make the margin of profit small when the selling price is uncertain.

As a means of diversification of products, however, salt cake offers an exceptional opportunity for many desert lake

plants such as those at Searles and Owens lakes. This is also true of soda ash. Production here of both salt cake and ash would not require the establishment of new camps or organizations and could be carried out as byproduct production. Such possibilities are under active consideration by several manufacturers.

Production of soda ash in the United States from natural brines has fallen, as has the price, during the past year. Production for domestic consumption has remained about the same, but there has been a lowering of export business, due to competition of foreign producers.

Chemicals—The California Chemical Company, with plants at Chula Vista and San Mateo, Calif., has brought its new Newark (Calif.) plant into production. This plant alone is producing in excess of 2,000 lb. of bromine per day; besides magnesium chloride liquors, a fine grade of chemical hydrated lime is made from oyster-shell deposits in San Francisco Bay. This company became associated during 1930 with a large Eastern chemical manufacturer. It is also producing heptane and bromoform. The latter is a byproduct that offers possibilities as a raw material for other chemical industries. Scheduled developments include the production of potash both as chloride and sulphate, as well as magnesia compounds. It is reported that present investments at Newark total over $1,000,000, with an equal investment projected.

A second plant for the production of iodine from the waste oil field brines in southern California has been brought into production.

The California subsidiary of the Philadelphia Quartz Company has increased its facilities at its Berkeley plant and is to begin the building of a $300,000 plant in the Los Angeles district. A. R. Maas is enlarging his trisodium phosphate plant at Los Angeles to double the 1930 output, and expects to add to his list of chemicals glaubers salts and monohydrate sodium carbonate. The second year of continued production has justified the establishment of the chlorine and caustic soda plants of the Hooker Electrochemical Company and Pennsylvania Salt Company at Tacoma, Wash. Paper Makers Chemical Company opened a plant in Portland, Ore., for the manufacture of rosin size.

The Standard Oil Company of California developed and began manufacture of an odorant to be added to natural gas and a new denaturant for industrial alcohol. The latter is not poisonous but of such characteristics as to make the alcohol non-potable. A new 2,500-gal. plant for the manufacture of alcohol from beet molasses began operation at Springville, Utah, near the close of the year.

Solid carbon dioxide plants are under construction in Los Angeles, Calif., and one reported near Price, Utah. The latter is to utilize the high concentration of carbon dioxide in the flow from a gas well. The new Los Angeles plant of the Liquid Carbonic Company is nearing completion. Smaller plants for grinding sulphur, production of turpentine and pine byproducts are beginning operation in California. The Kelco Company, of San Diego, Calif., began the production of several spray dried salts of alginic acid in 1930. These materials are finding many new and interesting uses as protective colloids.

Pulp and Paper—The Rainier Pulp & Paper Company, of Shelton, Wash., is now producing a satisfactory rayon grade of wood cellulose. This is the first of such production in the Northwest and is made from Western hemlock. The Fir-Tex Company, of St. Helens, Ore., has put into operation during the past year a $1,500,000 plant for the production of wall board from Douglas fir waste.

Two pulp mills began operation in 1930. These are the Olympic Forest Products Company at Port Angeles, Wash., and the Puget Sound Pulp & Timber Company, at Everett, Wash. Both of these plants started in midyear, each having an initial capacity of 175 tons daily of bleached sulphite pulp. Crown Zellerback Corporation rebuilt and enlarged its Camas (Wash.) mill during the year, adding new paper machines and bleached pulp equipment, but closed down permanently its Floriston (Calif.) plant, which had been the cause of much litigation over waste water disposal during recent years.

Soap and Rubber—The soap industry is another in which there has been large activity on the Pacific Coast. Procter & Gamble are building a $5,000,000 plant on a 15-acre tract at Long Beach, Calif. Soaps and vegetable fats are to be manufactured. The Los Angeles Soap Company is enlarging its plant with a new $250,000 unit.

The fabrication of rubber already is one of the Coast's major industries. With one automobile for every 2.3 people in California alone, the replacement market for tires is large. U. S. Rubber Company has entered the Los Angeles area by merging with the Samson Tire & Rubber Company. Invested in this district in the rubber industry is now a total of over $30,000,000. The total employment at capacity operation of the four large plants is about 10,000 men.

For some years the American Rubber Producers, Inc., have been conducting development work on the production of guayule rubber at Salinas, Calif. This work has now culminated in the building of a $150,000 plant which will be in operation in February. The company has 5,600 acres under cultivation. In a recent description of the work, Dr. David Spence stated that the output of 5,000 square miles planted to guayule under the cultivation system at present developed would supply the entire rubber requirements of the United States.

Several new consulting laboratories have been started during the past year and there has been unusual activity in research. The Twinning Laboratories, with a beautiful building at Fresno, Calif., is especially noteworthy. John W. Beckman, Oakland industrial and research chemist, has developed a process for liberating vegetable oils through bacterial action on the cell walls of the seed. Another process proposed by Mr. Beckman is for the catalytic reduction of sulphur dioxide to sulphur, employing carbon monoxide and other reducing gases made from natural gas. It is being given serious consideration as a means of overcoming the smelter smoke nuisance. Laboratory work indicates that costs will be very low and the very finely divided sulphur resulting will be suitable for insecticide work.

All in all, 1930 has been a very fair year in the Far West, a year of diverse developments, with a few setbacks but with the promise of more interesting developments in production and sales for 1931.

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Ammonia and Nitrogen Production

Preliminary statistics of ammonia production for 1929, recently released by the Census of Manufactures, show an actual production of 173,637,852 lb. of anhydrous ammonia—or approximately 38,000,000 lb. less than is indicated in the *Chem. & Met.* estimate, on page 41. It should be pointed out that the Census figure does not include the ammonia used at Hopewell for the manufacture of synthetic nitrate of soda, nor does it include the small quantity of ammonia converted to aqua at the factory.

Production Nitrogen and Fixed-Nitrogen Compounds, 1927-1929

	1929	1927
Total value*	$38,069,502	$26,085,661
Ammonia, aqua, including ammonia liquor:		
Pounds	†30,200,087	46,225,012
Value	$1,784,208	$1,260,426
Ammonia, anhydrous:		
Pounds	173,637,852	45,115,020
Value	$10,691,442	$4,011,362
Ammonium sulphate:		
Pounds	15,110,877	12,381,506
Value	$301,336	$266,426
Cyanogen compounds:		
Ferric ferrocyanide (Prussian blue)—		
Pounds	4,593,187	4,104,233
Value	$1,440,259	$1,364,537
Other cyanides, value	$5,250,957	$3,867,212
Hydrocyanic acid—		
Pounds	2,068,219	2,283,395
Value	$1,051,565	$1,078,770
Nitric acid:		
Tons	33,836	28,706
Value	$3,294,365	$3,559,436
Nitrous oxide (laughing gas):		
Thousands of gallons	116,479	66,392
Value	$1,296,392	$809,614
Other nitrogen compounds and gaseous nitrogen, value	$12,958,978	$9,867,878

*Not including ammonia products of the coke and manufactured gas industries.

†Ammonia (NH_3) content.

Chemicals Showed Downward Price Trend

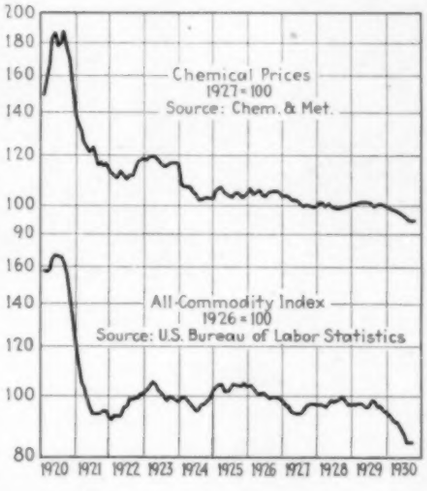
IN A period when industrial activity is of a recessive nature a corresponding reaction usually occurs in the price structure of the market. This was the case last year with reference to the price movement of chemicals. The extent of fluctuations may be measured by comparison of the weighted index number of *Chem. & Met.*, which in January, 1930, stood at 98.57, and in December was reported at 93.17.

Record production of many chemicals in 1929 established new standards for the individual producing units, and the desire to maintain these standards undoubtedly led to overproduction in the early part of the year and pressure of unsold stocks cannot be minimized as a price factor in reviewing the trend of values during the year. As manufacturing operations became adjusted more in line with consumptive requirements the influence of surplus stocks was lessened, but the fact that consuming industries held to a policy of small surpluses placed the burden of carrying stocks upon producers to a greater extent than is customary. As a result, the market was more or less under pressure throughout the year. Hence, to a large degree, price fluctuation in the market for chemicals last year can be traced to the logical working of the law of supply and demand.

LOWER production costs played a prominent part in fixing the position of many finished products. This is strikingly exemplified in the case of nitrogen-bearing chemicals. Fixation of nitrogen assumed a position of commercial importance where it was able to dictate the price for sulphate of ammonia and thereby affect sales figures for Chilean nitrates. Synthetic acetic acid assumed leadership in its field and not only set the price for this acid but also greatly restricted the field for acetate of lime. Acetone, citric acid, and synthetic methanol afford other examples where improved processes of manufacture have brought about a lowering in values not only in the materials directly produced but also in the status of materials with which they came into competition.

In addition to reduced production costs as represented by the introduction or increase of outputs of chemicals manufactured by new and improved processes, there was a logical decline in value of many selections in which no change in process was involved but where basic materials were available on more favorable terms.

THE line is so closely drawn between inter-material competition arising from low-cost production and the invasion of materials into new fields that



it is difficult to differentiate. It is largely because of the price position that new fields of consumption are opened up. For instance, methanol on a price consideration of a few years ago, could not be regarded seriously as a contender in the anti-freeze trade, yet considerable quantities were so disposed of during the past season. In contrast to this is the report that lime made inroads last year into the alkali field and that pressure in the market for caustic soda was accentuated by the release of large quantities which had been superseded in their regular distributive field by lime.

In the latter part of the year, unusual interest was shown in contract prices for alkalis and chlorine, because of the very low prices which were reported as the bases of transactions. These price reductions resulted from the keen competition which developed and evidently were due to the desire of producers to engage a fair share of production ahead and thus insure plant operations on a large scale during the ensuing year.

THE weighted index number for vegetable oils and fats was 93.89 in January and 72.69 in December, which explains very clearly the price trend in that market during the year. The decline in values was inclusive, as every kind of oil and fat closed at lower levels than prevailed in the early part of the year. Interchangeability is more general in oils than is the case in chemicals, and on that account low prices for one product has a wider effect upon the price level of the general market. World conditions also play a more prominent rôle. For instance, in the last year European markets cut down their requirements, and lessened buying from that quarter had a depressing effect upon primary markets, which were forced to seek larger than normal outlets in the United States. Exchange likewise favored domestic buyers in their purchases in foreign markets.

Supplies of oil of domestic origin also were large and the same was true for animal fats. Hence buyers were offered a choice of materials which were in direct competition.

Chem. & Met. Weighted Index of Chemical Prices

Base = 100 for 1927

This month	**89.68**
Last month	93.17
January, 1930	98.57
January, 1929	100.02

Basic chemicals, including soda ash, caustic soda, and liquid chlorine, sold at lower prices during the period. Lithopone also is moving at reduced levels. Aqua ammonia was under pressure, but anhydrous was firmer for January delivery.

Chem. & Met. Weighted Index of Prices for Oils and Fats

Base = 100 for 1927

This month	**70.65**
Last month	72.69
January, 1930	93.89
January, 1929	98.72

Linseed oil was easy and lower, and crude cottonseed oil likewise favored buyers. Tallow and oleo oil sold off, with practically no advances in the oil and fats list to counteract the downward trend of values.

Chemical Raw Materials for the Process Industries

Production, prices, imports and exports, and pertinent data on manufacturing processes, grades, and uses of almost a hundred chemical raw materials are included in the editorial supplement to this issue of *Chem. & Met.* As a companion compilation for the Materials of Construction chart, which appeared first as an editorial supplement in September, 1929, the reader of *Chem. & Met.* now has in condensed and readily available form, convenient reference sources for information on both process and construction materials.

CURRENT PRICES *in the* NEW YORK MARKET

THE following prices refer to round lots in the New York market. Where it is the trade custom to sell f.o.b. works, quotations are given on that basis and are so designated. Prices are corrected to Jan. 14.

Industrial Chemicals

	Current Price	Last Month	Last Year
Acetone, drums, lb.	$0.10 -$0.11	$0.11 -$0.12	$0.11 -$0.12
Acid, acetic, 28%, bbl., cwt.	2.60 - 2.85	2.60 - 2.85	3.88 - 4.03
Glacial 99%, tanks	8.98 -	- 8.98	-
drs.	9.23 - 9.48	9.23 - 9.48	-
U. S. P. reagent, c'boys.	9.73 - 9.98	9.73 - 9.98	-
Boric, bbl, lb.	.06½- .07	.06½- .07	.06½- .07
Citric, kegs, lb.	.40 - .41	.43½ - .45	.46 - .47
Formic, bbl, lb.	.10 - .11	.10 - .11	.10½ - .11
Gallic, tech., bbl., lb.	.50 - .55	.50 - .55	.50 - .55
Hydrofluoric 30% carb, lb.	.06 - .07	.06 - .07	.06 - .07
Lactic, 44%, tech., light, bbl., lb.	.11½- .12	.11½ - .12	.11½ - .12
22%, tech., light, bbl., lb.	.05½- .06	.05½ - .06	.05½ - .06
Muriatic, 18°, tanks, cwt.	1.00 - 1.10½	1.00 - 1.10	1.00 - 1.10
Nitric, 36°, carboys, lb.	.05 - .05½	.05 - .05½	.05 - .05½
Oleum, tanks, wks., ton.	18.50 -20.00	18.50 -	18.50- 20.00
Oxalic, crystals, bbl., lb.	.11 - .11½	.11 - .11½	.11½- .11½
Phosphoric, tech., c'bys., lb.	.08½- .09	.08½- .09	.08½ - .09
Sulphuric, 60°, tanks, ton.	11.00 -11.50	11.00 -11.50	11.00 -11.50
Tannic, tech., bbl., lb.	.25 - .35	.25 - .35	.35 - .40
Tartaric, powd., bbl., lb.	.31 - .33	.31 - .33	.35 - .40
Tungstic, bbl., lb.	1.40 - 1.50	1.40 - 1.50	1.40 - 1.50
Alcohol, ethyl, 190 p'f., bbl., gal.	2.63 -	2.63 - 2.71	2.68½ - 2.71
Alcohol, Butyl, tanks, lb.	.15½-	.16½- .17	.16½- .17
Alcohol, Amyl	-	-	-
From Pentane, tanks, lb.	.236-	.236-	-
Denatured, 188 proof			
No. 1 special dr., gal.	.39 -	.40 -	.52 -
No. 5, 188 proof, dr., gal.	.39 -	.40 -	.52 -
Alum, ammonia, lump, bbl., lb.	.03½- .04	.03½- .04	.03½- .04
Chrome, bbl., lb.	.04½- .05	.05 - .05½	.05½- .06
Potash, lump, bbl., lb.	.03½- .04	.03½- .04	.03 - .03½
Aluminum sulphate, com., bags, cwt.	1.40 - 1.45	1.40 - 1.45	1.40 - 1.45
Iron free, bg., cwt.	1.90 - 2.00	1.90 - 2.00	2.00 - 2.10
Aqua ammonia, 26°, drums., lb.	.03 - .04	.03 - .04	.03 - .04
tanks, lb.	.02½- .02½	.02½- .02½	-
Ammonia, anhydrous, cyl., lb.	.15½- .15½	.14 - .14½	.15 -
tanks, lb.	.05½-	.05½-	-
Ammonium carbonate, powd. tech., casks, lb.	.10½- .11	.10½- .11	.11 - .12
Sulphate, wks., cwt	1.70 -	1.75 -	2.10 -
Amylacetate tech., tanks, lb., gal.	.222-	2.22 -	-
Antimony Oxide, bbl., lb.	.08½- .10	.08½- .10	.09 - .10
Arsenic, white, powd., bbl., lb.	.04 - .04½	.04 - .04½	.04 - .04½
Red, powd., kegs., lb.	.09 - .10	.09 - .10	.09 - .10
Barium carbonate, bbl., ton.	58.00 -60.00	58.00 -60.00	58.00 -60.00
Chloride, bbl., ton	63.00 -65.00	63.00 -65.00	64.00 -70.00
Nitrate, cask, lb.	.07 - .07½	.07 - .07½	.07 - .07½
Blanc fixe, dry, bbl., lb.	.03½- .04	.03½- .04	.04 - .04½
Bleaching powder, f.o.b., wks., drums, cwt.	2.00 - 2.10	2.00 - 2.10	2.00 - 2.10
Borax, bbl., lb.	.033-	.033-	.033-
Bromine, cs., lb.	.45 - .47	.45 - .47	.45 - .47
Calcium acetate, bags	2.00 -	2.00 -	4.50 -
Arsenate, dr., lb	.07 - .08	.07 - .10	.07 - .08
Carbide drums, lb.	.05 - .06	.05 - .06	.05 - .06
Chloride, fused, dr., wks., ton.	20.00 -	20.00 -	20.00 -
flake, dr., wks., ton.	22.75 -	22.75 -	22.75 -
Phosphate, bbl., lb.	.08 - .08½	.08 - .08½	.08 - .08½
Carbon bisulphide, drums, lb.	.05 - .06	.05½- .06	.05 - .06
Tetrachloride drums, lb.	.06½- .07	.06½- .07	.06 - .07
Chlorine, liquid, tanks, wks., lb.	.01½-	.02 -	.02½-
Cylinders	.04 - .06	.04 - .06	.04½- .06
Cobalt oxide, cans, lb.	2.10 - 2.20	2.10 - 2.20	2.10 - 2.25
Copperas, bgs., f.o.b. wks., ton.	13.00 -14.00	13.00 -14.00	15.00 -16.00
Copper carbonate, bbl., lb.	.08½- .18	.08½- .17	.22 - .23
Cyanide, tech., bbl., lb.	.41 - .46	.41 - .46	.49 - .50
Sulphate, bbl., cwt.	4.00 - 4.25	4.25 - 4.50	5.50 - 6.00
Cream of tartar, bbl., lb.	.24½ - .26	.24½- .26	.26½- .27
Diethylene glycol, dr., lb.	.14 - .16	.14 - .16	.10 - .15
Epsom salt, dom., tech., bbl., cwt.	1.70 - 2.00	1.75 - 2.00	1.75 - 2.00
Imp., tech., bags, cwt	1.15 - 1.25	1.15 - 1.25	1.15 - 1.25
Ethyl acetate, drums, lb	.088-	.094-	.109-
Formaldehyde, 40%, bbl., lb.	.06 - .07	.06 - .07	.08½- .09
Furfural, dr., contract, lb.	.10 - .12	.10 - .12	.15 - .17
Fusel oil, crude, drums, gal.	1.30 - 1.40	1.30 - 1.40	1.30 - 1.40
Refined, dr., gal.	1.90 - 2.00	1.90 - 2.00	1.90 - 2.00
Glauber's salt, bags, cwt.	1.10 - 1.20	1.10 - 1.20	1.00 - 1.10
Glycerine, c.p., drums, extra., lb.	.12½- 13	.13 - .13½	.14 - .15
Lead:			
White, basic carbonate, dry casks, lb.	.07½-	.07½-	.09 -
White, basic sulphate, sck., lb.	.07 -	.07 -	.08½-
Red, dry, sck., lb.	.08½-	.08½-	.09½-
Lead acetate, white crys., bbl., lb.	11½- 12	11½- .12	.13 - .13½
Lead arsenate, powd., bbl., lb.	.13 - .14	.13 - .14	.13 - .14
Lime, chem., bulk, ton	8.50 -	8.50 -	8.50 -
Litharge, pwd., csk, lb.	.07½-	.07½-	.08½-
Lithopone, bags, lb.	.04½- .05	.05½- .06	.05½- .06½
Magnesium carb., tech., bags, lb.	.05 - .06½	.06 - .06½	.06½- .07
Methanol, 95%, tanks, gal.	.38 -	.38 -	.48 -
97%, tanks, gal.	.39 -	.39 -	.50 -
Synthetic, tanks, gal.	.40½-	.40½-	-
Nickel salt, double, bbl., lb.	.10½- .11	.13 - .13½	.13 - .13½
Single, bbl., lb.	.10½- .11	.13 - .13½	.13 - .13½
Orange mineral, csk., lb.	.10½-	.10½-	.11½-
Phosphorus, red, cases, lb.	.42 - .44	.42 - .44	.37½ - .42
Yellow, cases, lb.	.31 - .32	.31 - .32	.31 - .32
Potassium bichromate, casks, lb	.09 - .09½	.09 - .09½	.09 - .09½
Carbonate, 80-85%, calc., csk., lb	.05½- .06	.05½- .06	.05½- .06
Chlorate, powd., lb.	.08 - .08½	.08½- .09	.07½ - .08½
Cyanide, cs., lb.	.55 - .57	.55 - .57	.51 - .53
First sorts, csk., lb.	.08½- .09	.08½- .09	.08½- .09
Hydroxide (c'stic potash) dr., lb	.06½- .06½	.06½- .06½	.06½- .06½
Muriate, 80% bgs., ton.	37.15 -	37.15 -	36.75 -
Nitrate, bbl., lb.	.05½ .06	.06 - .06½	.06 - .07½
Permanganate, drums, lb.	.16 - .16½	.16 - .16½	.16 - .16½
Prussiate, yellow, casks, lb.	.18½ - .19½	.18½ - .19	.19 - .19½
Sal ammoniac, white, casks, lb	.04½- .05	.046- .05	.047- .05
Salsoda, bbl., cwt.	.90 - .95	.90 - .95	.90 - .95
Salt cake, bulk, ton	15.00 -18.00	15.00 -18.00	22.00 -25.00
Soda ash, light, 58%, bags, contract, cwt.	1.15 -	1.32 -	1.32 -
Dense, bags, cwt.	1.17½-	1.35 -	1.35 -
Soda, caustic, 76%, solid, drums, contract, cwt.	2.50 - 2.75	2.90 - 3.00	2.90 - 3.00
Acetate, works, bbl., lb.	.04½- .05	.04½- .05	.05 - .05½
Bicarbonate, bbl., cwt.	2.00 - 2.25	2.00 - 2.25	2.00 - 2.25
Bichromate, casks, lb.	.07 - .07½	.07 - .07½	.07 - .07½
Bisulphate, bulk, ton.	14.00 -16.00	14.00 -16.00	12.00 -15.00
Bisulphite, bbl., lb.	.03½- .04	.03½- .04	.03½- .04
Chlorate, kegs, lb.	.05½- .07½	.05½- .07½	.06½- .06½
Chloride, tech., ton	12.00 -14.75	12.00- 14.75	12.00 -14.00
Cyanide, cases, dom., lb.	.17 - .18	.17 - .18	.18 - .22
Fluoride, bbl., lb.	.08 - .08½	.08½- .09	.08½- .09
Hyposulphite, bbl., lb	2.40 - 2.50	2.40 - 2.50	2.50 - 3.00
Nitrate, bags, cwt.	2.03 -	2.02 -	2.10 -
Nitrite, casks, lb.	.07½- .08	.07½- .08	.07½- .08
Phosphate, dibasic, bbl., lb.	.02½- .03	.03 - .03½	.03½- .03½
Prussiate, yel. drums, lb	.11½- .12	.11½- .12	.11½- .12
Silicate (30°, drums), cwt.	.60 - .70	.60 - .70	.75 - 1.15
Sulphide, fused, 60-62%, dr., lb.	.02½- .03½	.02½- .03	.03½- .04
Sulphite, cyrs., bbl., lb	.03 - .03½	.03 - .03½	.02½- .03
Sulphur, crude at mine, bulk, ton	18.00 -	18.00 -	18.00 -
Chloride, dr., lb.	.05 - .06	.05 - .06	.04 - .05
Dioxide, cyl., lb.	.06½- .07	.06½- .07	.09 - .10
Flour, bag, cwt.	1.55 - 3.00	1.55 - 3.00	1.55 - 3.00
Tin bichloride, bbl., lb.	nom. -	nom. -	.13½-
Oxide, bbl., lb.	.29 -	.30 -	.42 -
Crystals, bbl., lb.	.25½-	.25 -	.32½-
Zinc chloride, gran., bbl., lb.	.06½- .06½	.06½- .06½	.06½- .06½
Carbonate, bbl., lb.	.10½- .11	.10½- .11	.10 - .11
Cyanide, dr., lb.	.41 - .42	.40 - .41	.40 - .41
Dust, bbl., lb.	.06 - .07	.07½- .08	.09 - .10
Zinc oxide, lead free, bag, lb.	.06½-	.06½-	.06½-
5% lead sulphate, bags, lb.	.06½-	.06½-	.06½-
Sulphate, bbl., cwt.	3.00 - 3.25	2.75 - 3.00	2.75 - 3.00

Oils and Fats

	Current Price	Last Month	Last Year
Castor oil, No. 3, bbl., lb.	$0.11½-$0.12½	$0.11½-$0.12½	$0.12½-$0.13
Chinawood oil, bbl., lb.	.07¼-	.07 -	.14½-
Coconut oil, Ceylon, tanks, N.Y., lb.	.05½-	.05½-	.07 -
Corn oil crude, tanks, (f.o.b. mill), lb.	.07½-	.07½-	.08 -
Cottonseed oil, crude (f.o.b. mill), tanks, lb.	.06½-	.06½-	.07½-
Linseed oil, raw, car lots, bbl., lb.	.088-	.094-	.14 -
Palm, Lagos, casks, lb	.06½-	.06½-	.07½-
Niger, casks, lb.	.06½-	.06½-	.07½-
Palm Kernel, bbl., lb.	.06½-	.06½-	.07½-
Peanut oil, crude, tanks (mill), lb.	.07 -	.07 -	.07½-
Rapeseed oil, refined, bbl., gal.	.54 - .56	.54 - .56	.71 - .73
Soya bean, tank (f.o.b. Coast), lb.	.08 -	.08½-	.09½-
Sulphur (olive foots), bbl., lb.	.06½-	.06 -	.08½-
Cod, Newfoundland, bbl., gal.	.45 - .50	.50 - .52	.57 - .60
Menhaden, light pressed, bbl., gal.	.40 - .42	.40 - .42	.64 - .66
Crude, tanks (f.o.b. factory), gal.	.20 -	.20 -	.43 -
Whale, crude, tanks, gal	.78 -	.78 -	- .80
Grease, yellow, loose, lb.	.03½-	.04½-	.06½-
Oleo stearine, lb.	.07½-	.08½-	.11½-
Red oil, distilled, d.p. bbl., lb.	.08½-	.08½-	.09½- .09½
Tallow, extra, loose, lb.	.04½-	.04½-	.07½-

Coal-Tar Products

	Current Price	Last Month	Last Year
Alpha-naphthol, crude, bbl., lb.	$0.60 -$0.65	$0.60 -$0.65	$0.60 -$0.62
Refined, bbl., lb.	.80 - .85	.80 - .85	.80 - .85
Alpha-naphthylamine, bbl., lb.	.32 - .34	.32 - .34	.35 - .36
Aniline oil, drums, extra, lb.	.14½- .15	.15 - .15½	.15 - .16
Aniline salts, bbl., lb.	.24 - .25	.24 - .25	.24 - .25
Anthracene, 80%, drums, lb.	.60 - .65	.60 - .65	.60 - .65

Coal-Tar Products (Continued)

	Current Price	Last Month	Last Year
Benzaldehyde, U.S.P., dr., lb.	1.10 - 1.25	1.15 - 1.35	1.15 - 1.25
Benzidine base, bbl., lb.	.65 - .67	.65 - .67	.65 - .67
Benzoic acid, U.S.P., kgs, lb.	.57 - .60	.57 - .60	.57 - .60
Benzyl chloride, tech., dr., lb.	.30 - .35	.30 - .35	.25 - .26
Benzol, 90%, tanks, works, gal.	.20 - .21	.21 - .23	.23 - .24
Beta-naphthol, tech., drums, lb.	.22 - .24	.22 - .24	.22 - .24
Cresol, U.S.P., dr., lb.	.14 - .17	.14 - .17	.14 - .17
Cresylic acid, 97%, dr., wks., gal.	.55 - .58	.58 - .61	.73 - .76
Diethylaniline, dr., lb.	.55 - .58	.55 - .58	.55 - .58
Dinitrophenol, bbl., lb.	.29 - .30	.29 - .30	.30 - .31
Dinitrotoleun, bbl., lb.	.16 - .17	.16 - .17	.17 - .18
Dip oil, 25% dr., gal.	.26 - .28	.26 - .28	.26 - .28
Diphenylamine, bbl., lb.	.38 - .40	.38 - .40	.42 - .44
H-acid, bbl., lb.	.65 - .70	.68 - .70	.63 - .55
Naphthalene, flake, bbl., lb.	.03½- .04½	.03½- .04½	.04½- .05
Nitrobenzene, dr., lb.	.08½- .09	.08½- .09	.08½- .10
Para-nitraniline, bbl., lb.	.51 - .55	.51 - .55	.52 - .53
Para-nitrotoluine, bbl., lb.	.29 - .30	.29 - .31	.28 - .32
Phenol, U.S.P., drums, lb.	.14½- .15	.14½- .15	.14½- .15
Picric acid, bbl., lb.	.30 - .40	.30 - .40	.30 - .40
Pyridine, dr., lb.	1.50 - 1.75	1.50 - 1.80	1.75 - 1.90
R-salt, bbl., lb.	.40 - .44	.40 - .44	.44 - .45
Resorcinal, tech., kegs, lb.	1.15 - 1.25	1.15 - 1.25	1.30 - 1.40
Salicylic acid, tech., bbl., lb.	.33 - .35	.33 - .35	.30 - .32
Solvent naphtha, w.w., tanks, gal	.25 - .30	.25 -	.30 - .....
Tolidine, bbl., lb.	.88 - .90	.88 - .90	.95 - .96
Toluene, tanks, works, gal.	.30 -	.30 -	.35 - .....
Xylene, com., tanks, gal.	.25 - .28	.25 - .28	.36 - .40

Miscellaneous

	Current Price	Last Month	Last Year
Barytes, grd., white, bbl., ton.	$23.00-$25.00	$23.00-$25.00	$23.00-$25.00
Casein, tech., bbl., lb.	09½- .12	.10½- .12	.14½- .16
China clay, dom., f.o.b. mine, to	8.00 -20.00	8.00 -20.00	10.00 -20.00
Dry colors:			
Carbon gas, black (wks.), lb.	.03½- .20	.04 - .22	.06 - .22
Prussian blue, bbl., lb.	.35 - .36	.35 - .36	.31 - .32
Ultramine blue, bbl., lb.	.06 - .32	.06 - .32	.03 - .35
Chrome green, bbl., lb.	.27 - .28	.27 - .28	.27 - .30
Carmine red, tins, lb.	4.40 - 4.80	4.40 - 4.80	5.25 - 5.50
Para toner, lb.	.75 - .80	.77 - .80	.70 - .80
Vermilion, English, bbl., lb.	1.75 - 1.90	1.75 - 1.90	1.80 - 1.85
Chrome yellow, C. P., bbl., lb.	16½- .17	.17 - .17½	.15½- .16
Feldspar, No. 1 (f.o.b. N.C.), to	6.50 - 7.50	6.50 - 7.50	6.50 - 7.50
Graphite, Ceylon, lump, bbl., lb.	.07 - .08½	.07 - .08½	.08 - .09
Cum copal Congo, bags, lb.	.06 - .08	.07 - .08	.07½- .08
Manila, bags, lb.	.16 - .17	.16 - .17	.15 - .18
Damar, Batavia, cases, lb.	.16 - .16½	.16 - .19	.22 - .23
Kauri No. 1 cases, lb.	.45 - .48	.48 - .53	.48 - .53
Kieselguhr (f.o.b. N. Y.), lb.	50.00 -55.00	50.00 -55.00	50.00 - 55.00
Magnesite, calc, ton	40.00 -.....	40.00 -.....	40.00 -.....
Pumice stone, lump, bbl., lb.	.05 - .07	.05 - .08	.05 - .07
Imported, casks, lb.	.03 - .40	.03 - .40	.03 - .35
Rosin, H., bbl.	5.35 -.....	5.35 -.....	8.70 -.....
Turpentine, gal.	.43½-	.41 -.....	.56½- .....
Shellac, orange, fine, bags, lb.	.41 - .42	.42 - .43	.59 - .60
Bleached, bonedry, bags, lb.	.28 - .30	.28 - .30	.46 - .48
T. N. bags, lb.	.17 - .18	.19 - .21	.33 - .35
Soapstone (f.o.b. Vt.), bags, ton	10.00 -12.00	10.00 -12.00	10.00 -12.00
Talc, 200 mesh (f.o.b. Vt.), ton.	8.00 - 8.50	9.50 -.....	10.50 -.....
300 mesh (f.o.b. Ga.), ton.	7.50 -10.00	7.50 -10.00	7.50 -11.00
225 mesh (f.o.b. N. Y.), ton.	13.75 -.....	13.75 -.....	13.75 -.....

	Current Price	Last Month	Last Year
Wax, Bayberry, bbl., lb.	$0.21 $0.24	$0.22 $0.24	$0.27 -$0.29
Beeswax, ref., light, lb.	29 - .30	33 - .35	.37 - .39
Candelilla, bags, lb.	15 - .16	.16 - .18	.21 - .23
Carnauba, No. 1, bags, lb.	24 - .25	.26 - .27	32 - .33
Paraffine, crude 105-110 m.p., lb.	.03½ - .03¾	.04 - .05	.04¾ - .05

Ferro-Alloys

	Current Price	Last Month	Last Year
Ferrotitanium, 15-18%, ton.	$200.00	$200.00-.....	$200.00 .....
Ferromanganese, 78-82%, ton.	80.00 85.00	94.00-99.00	100.00 .....
Spiegeleisen, 19-21%, ton.	30.00	33.00-.....	33.00 .....
Ferrosilicon, 14-17%, ton.	39.00	39.00-.....	45.00-.....
Ferrotungsten, 70-80%, lb.	1.10	1.10-.....	1.45 .....
Ferrovanadium, 30-40%, lb.	3.15- 3.50	3.15- 3.75	3.15-3.75

Non-Ferrous Metals

	Current Price	Last Month	Last Year
Copper, electrolytic, lb.	$0.10	$0.10¾-.....	$0.17½-.....
Aluminum, 96-99%, lb.	.233-.....	.233-.....	.24 - .25
Antimony, Chin. and Jap., lb.	073 -.....	.0705	.08½-.....
Nickel, 99%, lb.	.35 -.....	.35 -.....	.35 -.....
Monel metal, blocks, lb.	.28 -.....	.28 -.....	.28 -.....
Tin, 5-ton lots, Straits, lb.	.25½-.....	.251-	39¼ - .....
Lead, New York, spot, lb.	.04½-	.051-	06¼ - .....
Zinc, New York, spot, lb.	.0435-.....	.045-	.056 -.....
Silver, commercial, oz.	.30½-	.33½	.45¾-.....
Cadmium, lb.	.70 - .75	.70 - .75	85 - .95
Bismuth, ton lots, lb.	1.25 -	1.00 -.....	1.70 -.....
Cobalt, lb.	2.50 -	2.50 - 2.50	2.50 - ....
Magnesium, ingots, 99%, lb.	.48 -.....	.48 -.....	85 - 1.10
Platinum, ref., oz.	36.00	36.00	65.00 66.00
Palladium ref., oz.	21.00- 22.00	22.00- 23.00	35.00-36.00
Mercury, flask, 75 lb.	105.00 107.00	105.00-107.00	124.00-.....
Tungsten powder, lb.	1.65-.....	1.55- 1.60	1.35- 1.50

Ores and Semi-finished Products

	Current Price	Last Month	Last Year
Bauxite, crushed, wks., ton.	$6.50- $8.25	$6.50- $8.25	$5.50- $8.75
Chrome ore, c.f. post, ton.	19.50- 24.00	19.50- 24.00	22.00- 23.00
Coke, fdry., f.o.b. ovens, ton.	2.75- 2.85	2.75- 3.85	2.85- 3.00
Fluorspar, gravel, f.o.b. Ill., ton.	17.25- 20.00	17.25- 20.00	18.00- 20.00
Manganese ore, 50% Mn., c.i.f. Atlantic Ports, unit.	27 - 28	.31 - .36	31 - 36
Molybdenite, 85% MoS_2 per lb. MoS_2, N. Y., lb.	.35 - .40	.33 - .35	48 - 50
Monazite, 6% of ThO_2, ton.	60.00 -.....	60.00 -.....	60.00-.....
Pyrites, Span. fines, c.i.f., unit.	.13 -.....	.13 -.....	.13 -.....
Rutile, 94-96% TiO_2, lb.	.10 - .11	.10 - .11	.11 - .13
Tungsten, scheelite, 60% WO_3 and over, unit.	12.00 - 12.50	12.25 -13.50	15.25 -16.50

CURRENT INDUSTRIAL DEVELOPMENTS

New Construction and Machinery Requirements

Bronze Foundry—General Bronze Corp., 34-19 10th Ave., Long Island City, N. Y., will receive bids after Mar. 15 for additions and consolidations of bronze foundry. Private plans.

Copper and Brass Factory—Oshawa Industrial Foundation, Ltd., c/o Chamber of Commerce, Oshawa, Ont., plans the construction of a 1 story, 100 x 150 ft. factory. Estimated cost $60,000. Coulter Mfg. Co., c/o Coulter Copper & Brass Co. Ltd., 115 Sumach St., Toronto, is lessee.

Calorizing Plant—The Calorizing Co., M. E. Ward, 400 Hill Ave., Wilkinsburg, Pa., has work under way on the construction of a 1 story, 80 x 140 ft. calorizing plant. The Austin Co., Union Trust Bldg., Pittsburgh, are contractors.

Carbon Bi-Sulphide, Plant, Enamel, etc.—A. L. Flint, General Purchasing Officer of the Panama Canal, Washington, D. C., will receive bids until Jan. 20 for carbon bi-sulphide, rosin, paint, enamel, etc.

Cement Plant—Canada Cement Co., Ltd., H. O. Canada Cement Bldg., Montreal, Que., plans the construction of a new cement plant, 500 tons daily capacity, including elecrtic power, cement making kilns and equipment, coveyors, storage bins, etc., at Port Colborne, Ont. Estimated cost $500,000. S. H. Barr, H. O. Canada Cement Bldg., Montreal, is chief engineer.

Bauxite Plant — Merrimac Chemical Co., Everett, Mass., awarded contract for rebuilding 1 and 3 story bauxite plant, to J. M. and C. J. Buckley Co., 183 Essex St., Boston. Estimated cost $40,000 to $50,000. Also 1 story nitric acid building to P. J. MacNaughton & Co., Inc., 711 Boylston St., Boston. $50,000.

Chemical Plant—Dewey & Almy Chemical Co., 4000 East 8th St., Oakland, Calif., awarded contract for the construction of a 2 story chemical plant to H. K. Henderson, 393 40th St., Oakland. Estimated cost $10,000.

Chemical and Drug Manufacturing Plant—Novocol Chemical Mfg. Co., M. Nevins, Pres., Atlantic Ave. and Ashford St., Brooklyn, N. Y., plans the construction of a chemical and drug manufacturing plant. Estimated cost including equipment, $40,000. W. A. Lacerenza, 26 Court St., Brooklyn, is architect.

Nitric Acid Plant—E. I. DuPont de Nemours & Co., DuPont Bldg., Wilmington, Del., had plans prepared for the construction of a nitric acid plant and manufacturing and chemical buildings at Barksdale. Estimated cost to exceed $40,000. Private plans. Work will be done by day labor and separate contracts.

Coal Tar Products Plant—Barrett & Co., 40 Rector St., New York, N. Y., will soon award contract for the construction of a group of buildings for the manufacture of coal tar products at 36th St. and Grays Ferry Rd., Philadelphia, Pa. Private plans.

Creosoting Plant—Atchison, Topeka & Santa Fe Ry. Co., Amarillo, Tex., is having plans prepared for the construction of a plant for creosoting railroad ties, including high pressure operated rooms for forcing creosote into the ties at Presidio. Estimated cost $100,000. W. W. Kelly, Amarillo, is chief engineer (Western Lines).

Fertilizer Plants—International Fertilizer Co., Quebec City, Que., plans the construction of plants at St. John, N. B., and Levis, Que. Estimated cost $40,000 and $50,000 respectively.

Fireworks Plant — T. W. Hand Fireworks Co. Ltd., Dixie, Ont., plans addition to plant. Estimated cost $100,000.

Fireworks Manufacturing Plant—Unexcelled Mfg. Co., 22 Park Pl., New York, N. Y., will build a plant at Cranbury, N. J. Estimated cost to exceed $40,000. Work will be done by day labor and separate contracts.

Gas Manufacturing Plant — Public Service Electric & Gas Co., 80 Park Pl., Newark, N. J., awarded contract for the construction of a 2 story gas manufacturing plant on Duffield Ave., Jersey City, to United Engineers & Constructors, Inc., 80 Park Pl., Newark. Estimated cost $50,000.

Gas Manufacturing Plant — United Soviet Socialist Russia, c/o Amtorg Corp., 261 5th Ave., New York, N. Y., will build a gas manufacturing plant and gas pipe lines at Moscow and other locations. Estimated cost to exceed $5,000,000. Lucas & Luick, 231 South La Salle St., Chicago, Ill., are engineers. Work will be done by day labor and separate contracts.

Gas Plant — Central Hudson Gas & Electric Corp., South Rd., Poughkeepsie, N. Y., has been granted permit to construct a gas plant at New Windsor (mail Newburgh), also gas distribution system from plant at Newburgh through town of New Windsor to serve Clancyville and New Windsor.

Gas Plant Addition—Brockton Gas Light Co. Inc., 54 Main St., Brockton, Mass., is having preliminary plans prepared for a 2 story addition to gas plant at Grove and Union Sts. Estimated cost $40,000. C. H. Tenney Co., 38 Chauncy St., Boston, are engineers.

Glass Plant—Libby Glass Co., Ash St. and Wheeling Lake E. R., Toledo, O., awarded contract for the design and construction of a glass plant including new blowing machines, three furnaces, lehrs and other equipment necessary for a output of 40,000,000 tumblers per year, also new warehouse, engine room, machine shop, boiler house, producer house and batch mixer buildings, to H. K. Ferguson Co., Hanna Bldg., Cleveland. Estimated cost $600,000.

Plaster Mill—Standard Gypsum Co. of Canada Ltd., Vancouver, B. C., plans the construction of a plaster mill. Estimated cost $100,000.

Laboratory—Bd. of Education, J. A. Bonar, Supt. of Buildings, Administration Bldg., Pittsburgh, Pa., awarded contract for the construction of a 4 story, 223 x 383 ft. junior high and elementary school, including general science laboratory, etc., at Butler and 40th Sts., to Pittsburgh Engineering & Construction Co., 511 North Homewood St., Pittsburgh. Estimated cost $1,250,000.

Laboratory—New Britain General Hospital, 9 Grand St., New Britain, Conn., is having preliminary plans prepared for addition to nurses' home, including laboratory, etc. Estimated cost $150,000. Stevens & Lee, 45 Newbury St., Boston, Mass., are architects.

Laboratory—State Medical College, Galveston, Tex., will soon receive bids for the construction of a 2 and 3 story laboratory. Estimated cost $400,000. H. Giesecke, c/o A. & M. College, and associates, Bryant, are architects.

Laboratory—U. S. Veterans Bureau, Washington, D. C., will soon receive bids for the construction of a group of hospital buildings, including nurses' home, laboratory, heating plant, etc., at Waco, Tex. Estimated cost $1,200,000. J. A. Wetmore, Washington, D. C., is supervising architect.

Laboratory—University of South Carolina, D. M. Douglas, Pres., Columbia, S. C., awarded contract for the construction of a new building, including laboratory, etc., to J. J. McDevitt Co., Charlotte, N. D. Estimated cost $230,175.

Laboratory (Biological) — Dept. of Health, Municipal Bldg., New York, N. Y., will receive bids about Apr. 1 for the construction of a biological laboratory on 16th St. Sibley & Fetherstone, 205 East 42nd St., New York, are architects.

Laboratory (Experimental)—Memorial Hospital, 2 West 106th St., New York, N. Y., awarded contract for the construction of a 3 story experimental laboratory for X-Ray to Sobray Whitcomb, 105 West 4th St., New York. Estimated cost $40,000.

Laboratory (Physics)—Massachusetts Institute of Technology, Cambridge, Mass., awarded contract for a 5 story, 50 x 300 ft. physics laboratory on Charles River Rd., to Stone & Webster, 49 Federal St., Boston. Estimated cost $800,000.

Laboratory (Physical and Chemical)—Mount Holyoke College, M. E. Woolley, Pres., South Hadley, Mass., will soon receive bids for a 1 and 2 story physical and chemical laboratory, etc. Estimated cost $150,000. Putnam & Cox, 114 State St., Boston, are architects.

Laboratories (Biological and Chemistry) — Hastings College, C. H. French, Hastings, Neb., plans the construction of a group of buildings, including biological and chemistry laboratories, heating plant, etc. Estimated cost $760,000. Architect not selected.

Magazine Buildings — Public Works Officer, Third Naval Dist., Headquarters, Washington and Christopher Sts., New York, N. Y., awarded contract for remodeling and extending two magazine buildings at Naval Ammunition Dept., Iona Island, to S. Pasquale Co., 91 Williams St., Jamaica Plain, Mass., $34,518.

Mine Filling Plant — Bureau of Yards & Docks, Navy Dept., Washington, D. C., awarded contract for the construction of a mine filling plant at Hawthorne, Nev., to C. F. Dinsmore Co., Ogden, Utah. $333,800.

Nitrating Plant — American Smokeless Powder Co., Acton, Mass., plans the reconstruction of nitrating plant recently destroyed by fire. Estimated cost $40,000. Architect not selected.

Oxygen Manufacturing Plant — Linde Air Products Co., El Paso, Tex., subsidiary of Union Carbide & Carbon Co., 30 East 42nd St., New York, N. Y., plans the construction of a 2 story oxygen manufacturing plant. Estimated cost $100,000. Private plans.

Paint and Tile Manufacturing Plants—P. N. Anger & Associates, 660 Prairie St., Beaumont, Tex., is having plans prepared for the construction of a plant for the manufacture of paint and tile from magnesite, magnesium, chloride compounds. Private plans. Machinery and equipment will be required.

INDUSTRIAL BUILDING CONTRACTS IN 1929 AND 1930

($40,000 or More)

	1930		1929	
	No.	Value Thousands	No.	Value Thousands
Aircraft	5	$2,230	31	$14,818
Automotive	22	6,380	291	28,962
Garages	225	18,090		
Chemicals, fine	9	855	5	665
Chemicals, heavy	40	13,527	56	7,796
Clay products	14	1,254	25	3,620
Coke	4	1,179	3	230
Cold storage warehouses	16	9,727	19	3,327
Other warehouses	141	31,361	85	12,184
Electric power plants	194	86,137	164	151,033
Explosives	2	215	1	40
Fertilizer	3	205	2	300
Foundries	29	2,146	41	4,150
Glass	7	650	14	10,425
Iron and steel and their products	69	34,083	107	48,920
Leather	12	695	12	1,284
Cement	3	165	6	2,255
Lumber and woodworking	17	1,400	26	4,857
Machine shops	81	6,153	103	13,850
Manufactured gas	11	4,110	14	2,178
Oils, vegetable and animal	2	370	1	40
Paint and varnish	8	750	10	605
Paper and pulp	13	4,777	26	21,136
Petroleum products	52	15,600	46	55,346
Printing and binding	37	6,938	55	8,639
Pyroxylin products	5	2,240	3	2,240
Radio	3	221	14	3,194
Rayon	1	75	3	660
Other textiles	24	3,300	101	9,705
Rubber products	13	1,269	35	9,273
Soap	5	2,450	6	1,700
Sugar	....	.....	3	280
Other food products	233	21,289	246	31,858
Process industries not previously mentioned	14	2,355	9	2,255
Miscellaneous factories	345	48,975	644	89,488
Total	1,659	$331,171	2,207	$547,313

Decline in 1930—Number, 25.0 per cent; value, 39.4 per cent.

Paper Plant — Handmade Papers Ltd., subsidiary of Don Valley Paper Co., Leaside, Ont., plans the construction of a paper plant at Toronto. Initial cost $100,000.

Paper Plant—Standard Paper Co., 40-42 Market St., Hartford, Conn., will soon award contract for a 3 story, 50 x 155 ft. warehouse, service building, office, etc. Estimated cost $100,000. A. Feinberg, 1127 Main St., Hartford, is architect.

Paper Products Plant — Schmidt Lithograph Co., Second and Bryant Sts., San Francisco, Calif., acquired a site and plans the construction of a plant for the manufacture of paper products in Boggs Tract, Stockton. Estimated cost to exceed $150,000.

Perfumery Plant—Yardley & Co. Ltd., 108 Palisade Ave., Union City, N. J., will soon award contract for a 1 story addition to perfumery plant. Estimated cost $40,000. Lockwood Green Engrs., Inc., 100 East 42nd St., New York, N. Y., are architects and engineers.

Potash Development—Del Stephens & Associates, Moore Bldg., San Antonio, Tex., plan development of potash and silica deposits in Lynn county near Tahoka. Private plans. Complete machinery and equipment will be installed.

Rayon Factory—Courtaulds Ltd., Cornwall, Ont., awarded contract for the construction of a plant for the manufacture of rayon silk, to Foundation Co. of Canada Ltd., 1538 Sherbrook St., Montreal, Que. Estimated cost to exceed $150,000.

Oil Mill—H. Dittlinger Roller Mills Co., New Braunfels, Tex., acquired the Landa Industries and is having surveys made for extensions and improvements including oil mill, flour mill, etc. Some machinery and equipment will be required.

Oil Mill — Owner, c/o B. Hudgins, Secy., Chamber of Commerce, Edinburg, Tex., is having preliminary surveys made for the construction of a cotton seed oil mill, 50,000 tons annual capacity. Estimated cost $75,000.

Refinery (Oil)—Marathon Oil Co., Thompson Bldg., Tulsa, Okla., plans extensions and improvements to oil refinery and distribution system, including new unit, new equipment, etc., at Del Rio, Tex. Private plans.

Refinery (Oil)—Standard Oil Co. of Ohio, Midland Bank Bldg., Cleveland, O., awarded contract for nine 3,000 bbl. oil storage tanks to Chicago Bridge & Iron Co., also soon takes bids for structural steel loading racks in connection with oil refinery improvements at Broadway and East 34th St. Estimated total cost $175,000. J. F. Harrison, Midland Bank Bldg., Cleveland, is engineer.

Refinery (Oil)—Texas & Pacific Coal & Oil Co., Temple, Tex., plans the construction of an oil refinery. Estimated cost $500,000. Private plans. Part of work will be done by owner's forces.

Refinery (Corn Sugar)—Corn Products Refining Co., 17 Battery Pl., New York, N. Y., plans the construction of a new corn sugar refinery to include machine shop, power house, etc., at Pekin, Ill., $2,000,000; also additions to refinery at Kansas City, Mo. Cost exceeds $200,000.

Refinery (Sugar) — Holly Sugar Co., West Channel, Stockton, Calif., plans the construction of a sugar refinery at Stockton, also warehouse at Tracy. Estimated cost $150,000 each.

Roofing Factory—Hyatt Jumbo Roofing Co., 10 Aylmer St., Windsor, Ont., plans the construction of and equipment for roofing plant on Richmond St., London. Estimated cost $100,000. Private plans.

Rubber Factory—Dominion Rubber Co. Ltd., Montreal, Que., plans addition to rubber plant on Notre Dame St. E. Estimated cost $100,000.

Slate Factory — Brownsville Slate Co., c/o L. H. Alline, Presque Isle, Me., plans addition and alterations to slate factory at Brownsville. Estimated cost $40,000 to $50,000. Private plans.

Tire Manufacturing Plant—Firestone de La Argentina, subsidiary of Firestone Tire & Rubber Co., Main St., Akron, O., awarded contract for design and construction of a new tire manufacturing plant and power house at Buenos Aires, Argentina, to Dwight P. Robinson & Co., div. of United Engineers & Constructors Inc., 112 North Broad St., Philadelphia, Pa.

Serum Plant—Sioux City Serum Co., Stock Yards, Sioux City, Ia., awarded general contract for the construction of a serum plant to Coomer & Small, 312 United Bank Bldg., Sioux City. Estimated cost $50,000.

Steel Mill—Otis Steel Co., 3341 Jennings Rd., Cleveland, O., awarded contract for the construction, equipment and installation of a continuous strip steel mill to United Engineering & Foundry Co., Farmers Bldg., Pittsburgh, Pa. Estimated cost $1,800,000.

Steel Plant — Ford Motor Co., Dearborn, Mich., will soon award contract for caisson work for foundation for mixer and furnace, open hearth steel plant. Giffels & Vallet, 604 Marquette Bldg., Detroit, are engineers.

Tile Manufacturing Plant—Ceramic Products Co., Independence, Mo., acquired building at San Antonio, Tex., and plans installation of machinery and equipment for the manufacture of architectural tile, etc. Estimated cost $125,000. Owner is purchasing all equipment and machinery.

Waterproofing Plant — Tremco Mfg. Co. of Canada Ltd., subsidiary of Tremco Mfg. Co., 393 East 131st St., Cleveland, O., acquired a site at Leaside and plans the construction of a 2 story plant for the manufacture of waterproofing and other compounds.

Yeast Factory—Anheuser-Busch Inc., c/o A. A. Busch, Pres., 721 Pestalozzi St., St. Louis, Mo., awarded contract for the construction of a yeast factory, 100,000 lbs. daily capacity, to include garage, machine shop, power plant, etc., at Old Bridge, N. J., to Stone & Webster Engineering Corp., 120 Broadway, New York, N. Y. Estimated cost $2,000,000.

CHEMICAL & METALLURGICAL ENGINEERING

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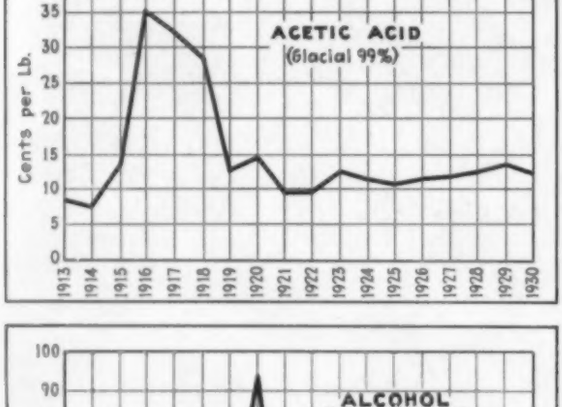

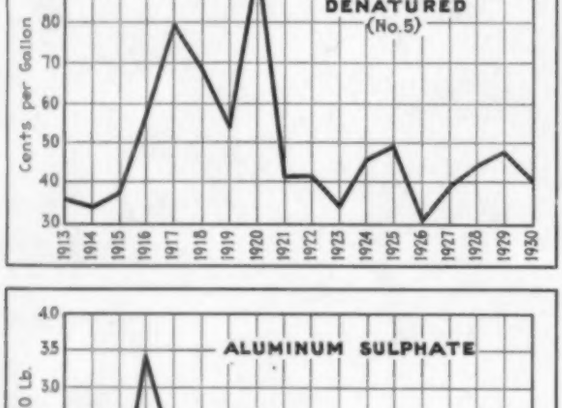

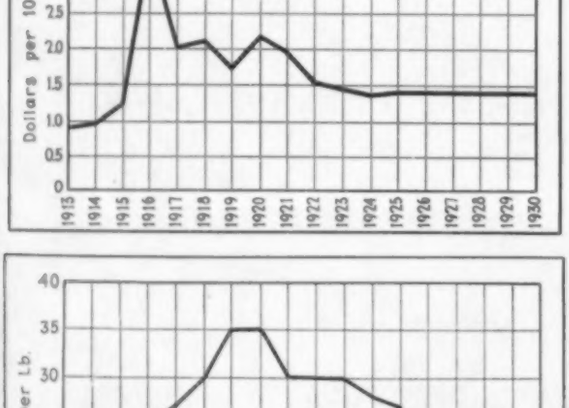

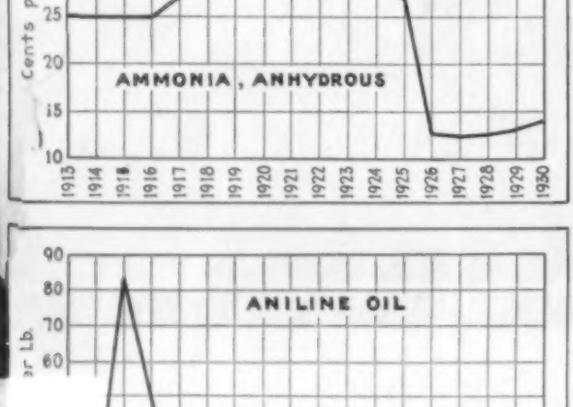

NO.	COMMODITY	FORMULA	GRADES	RAW MA
1	**Acetic Acid**	CH_3 (COOH)	28, 56, 80, and 99% (glacial)	Calcium acetate neous acid, calc
2	**Acetone**	$(CH_3)_2$ CO	Technical; U. S. P.; C.P.	Corn; calcium a
3	**Alum, Ammonium**	$Al_2(NH_4)_2(SO_4)_4$ .24 H_2O	Technical, U. S. P., C.P.; lumps, powder	Bauxite or Al_2 SO_4
4	**Alum, Sodium**	$Al_2Na_2(SO_4)_4$ .24 H_2O	Technical; U. S. P.; crystals	Bauxite or Al_2 (S
5	**Aluminum Chloride**	Al Cl_3	Anhydrous; hydrated white powder; solution of 30-35%	Bauxite, Al met
6	**Aluminum Sulphate**	$Al_2(SO_4)_3.18H_2O$	Commercial: >0.1% Fe_2O_3 Iron-free: <0.1% Fe_2O_3	Bauxite; iron-fr
7	**Ammonia, Anhydrous**	NH_3	Technical	Ammonia liquor drogen
8	**Ammonia, Aqua**	NH_3 . H_2O	Technical, U. S. P., C. P., 16, 20, and 26 deg.	Coal (ammonia and hydrogen
9	**Ammonium Chloride**	NH_4Cl	White; gray	Ammonia, HCl
10	**Ammonium Sulphate**	$(NH_4)_2SO_4$	Technical	Ammonia, H_2SO gen
11	**Amyl Acetate**	$CH_3.COO.C_5H_{11}$	Technical; U. S. P.	Acetic acid; amy
12	**Amyl Alcohol**	$C_5H_{11}OH$	Technical; C. P.	Fusel oil; pentan
13	**Arsenic White** (Oxide)	As_2O_3	Refined: 99% As_2O_3; crude, gray: 92-96% As_2O_3	Arsenic ores; flu lead smelters
14	**Barium Chloride**	$BaCl_2.2H_2O$	Technical: 98-99%; C. P.: at least 99.8%	Barium sulphide witherite, HCl
15	**Benzene** (Benzol)	C_6H_6	90%; pure	Coke-oven gas,
16	**Bleaching Powder**	CaO CaCl (OCl). H_2O	Technical: 35-37% available Cl	Lime, chlorine
17	**Borax** (Sodium tetraborate)	$Na_2B_2O_4$	Common, prismatic: 10 mol. of H_2O octahedral: 5 mol. of H_2O	Colemanite, soda rasorite; ulexite
18	**Butyl Acetate**	$CH_3.COO.C_4H_9$	Technical; pure	Butyl alcohol, a
19	**Butyl Alcohol**	C_4H_9OH	Technical: 98-100% n—butanol	Starch from co petroleum hydr
20	**Calcium Acetate**	$Ca(C_2H_3O_2)_2$ H_2O	Pure; technical: 80-82%	Pyroligneous aci
21	**Calcium Carbide**	CaC_2	Technical	Lime, coke
22	**Calcium Chloride**	$CaCl_2$	Fused; flaked	Salt brines; lime
23	**Carbon Bisulphide**	CS_2	Technical; U. S. P.	Sulphur, coke
24	**Carbon Dioxide**	CO_2	Technical: Liquid; Solid	Coke, limestone
25	**Carbon Tetrachloride**	CCl_4	Technical; U. S. P.; C. P.	Chlorine, carbon
26	**Chlorine**	Cl_2	Technical	Sodium chloride
27	**Chromic Acid**	Cr_2O_3	Technical; pure: 98-99%	Imported chrom ore
28	**Citric Acid**	$C_6H_8O_7$	Technical; U. S. P.	

MICAL RAW MATERIALS
FOR THE
ROCESS INDUSTRIES

RAW MATERIALS	MFG. PROCESSES	YEAR	PRODUCTION	IMPORTS	EXPORTS	AVERAGE PRICES	TARIFF (1930)	USES
Calcium acetate, ethylene, pyroligneous acid, calcium carbide, alcohol	Calcium acetate and acid; organic synthesis; fermentation	1929 1927 1919	[1] 85,780,036 lb. 95,933,705 62,380,290	29,235,000 lb. 10,551,016 1,850,427	Not reported	$13.68 11.90 12.74 } Per 100 lb., 99% bbl.	1½c. per lb., 65% or less. 2c. per lb.—>65%	Acetates; acetic anhydride; t tiles; lead pigments; leather
Corn; calcium acetate; propylene	Calcium acetate distillation; fermentation; organic synthesis	1929 1927 1919	[2] 35,276,549 lb. 6,045,914	68,703 lb. 266,223 240,223	7,897,000 lb. Not shown	13.8c. 12½ 15½ per lb. } Per lb. drums	20% ad valorem	Acetylene solvent; rayon; a ficial leather; films; smoke powder; lacq.; varnish remov
Bauxite or $Al_2(SO_4)_3$ and $(NH_4)_2SO_4$	Crystallization from sulphate mixture	1929 1927 1919	10,540,000 lb. 10,822,000 7,898,000	96,931 lb. 193,500 686,576 (incl. $Al_2(SO_4)_3$		3.25c. lb. 3.30 4.45	¼c. per lb.	Paper, leather, and textil medicine; baking powders
Bauxite or $Al_2(SO_4)_3$ and NaCl	Crystallisation from $Al_2(SO_4)_3$ and NaCl solution	1929 1927 1919	34,504,000 lb. 38,908,000 Not shown	Not separately shown		3.40c. lb. 3.55 4.60	¼ to ½c. per lb.	Dyeing; tanning; color lake baking powders; medicine
Bauxite, Al metal; chlorine, HCl	Chlorination of bauxite; Al + HCl	1929 1927 1919	33,102,000 lb. 34,260,000 9,612,000	Not shown	Not shown	5c. 15 $1.50 } Lb., anhydrous	25% n. s. p. f.	Petroleum refining; organic s thesis; carbonising wool; t ning
Bauxite; iron-free alumina; H_2SO_4	Bauxite or alumina hydrate and H_2SO_4	1929 1927 1919	347,089 tons 312,018 312,872	1,262 tons 766 110	26,588 tons 21,128	$1.40 1.40 1.70 } Per 100 lb., commerc.	½ to ½c. per lb.	Water purification; paper; dy ing; tanning
Ammonia liquor; nitrogen and hydrogen	Coal processing; nitrogen fixation	1929 1927 1919	[3] 173,637,852 lb. 45,115,020 25,648,050	56 lb.	2,329,100 lb.	13c. lb. 12.5 35	2½c. per lb.	Refrigeration; fertilisers; nit acid; organic preparations
Coal (ammonia liquor); nitrogen and hydrogen	Coal processing; nitrogen fixation	1929 1927 1919	[3,4] 30,200,087 lb. 45,115,020 45,476,000	Not shown	Not shown	3c. 2.76 7.5 c. lb., c.l. drum, } Lb., 26° 25% Ad. val.		Fertilisers; anhydrous ammon textiles; rayon, rubber; ph maceuticals
Ammonia, HCl	Aqua ammonia and HCl; crystallization from NaCl and $(NH_4)_2SO_4$ Sol.	1929 1927 1919	Not shown Not shown 13,212,619 lb.	9,561,000 lb. 14,279,000 2,011,028		4.6c. 5.5 11.8 } Lb., casks, white	2½c. lb.	Dry batteries; textile dyei soldering and galvanising; me cine
Ammonia, H_2SO_4; nitrogen, hydrogen	Coal processing; nitrogen fixation	1929 1927 1919	764,000 tons 620,500 288,800	19,052 tons 17,153 2,354	145,189 lb. 138,692	$2.20 2.40 4.42 } 100 lb., works	1½c. per lb.	Fertilisers; ammonium salts; fi proofing fabrics
Acetic acid; amyl alcohol, fusel oil	Esterification of fusel oil; organic synthesis	1929 1927 1919	5,832,145 lb. 2,421,301 906,764	300 lb. 300		$1.75-2.00 2.16 3.70 } Gal. drums, tech.	7c. per lb.	Paints, lacquers; pyroxylin s vent; perfumes; flavoring tracts
Fusel oil; pentane, Cl and NaOH	Refining fusel oil; organic synthesis	1929 1927 1919	[5] 390,963 gal. 182,054 gal. [6] 2,703,844 lb. 241,254 gal.	14,840 lb. 4,768 1,464,500		$1.90 2.50 4.05 } Gal., refined	6c. per lb.	Amyl acetate; organic synthes solvent
Arsenic ores; flue dust of copper and lead smelters	Byproduct in ore extraction of metals	1929 1927 1919	11,123 tons 10,315 6,029	13,157 tons 12,517 4,389		4c. lb., kegs 6.5 9.5	Free	Insecticides; decolorising pot a tank glass; weed killers; cat sheep dips
Barium sulphide, calcium chloride; witherite, HCl	Heating BaS with $CaCl_2$; treating witherite with HCl	1929 1927 1919	Not shown 3,334 tons 4,371	156,640 lb. 3,154,853 1,099,686		$63.50 57.38 82.30 ton	2c. per lb.	Pigments; barium chemicals; s brine purification; leather, t tiles
Coke-oven gas, coal tar	Coal processing and tar distillation	1929 1927 1919	127,929,074 gal. 111,739,966 63,077,463	18,164,952 lb. 3,240,132 1,509,861	33,346,000 25,794,000 } Lb., crude 14,268,419 lb.	22.5c. 22.91 23.5 lb., 90%	Free	Motor fuel; solvent, paint r movers; organic chemicals
Lime, chlorine	Absorbing chlorine in slaked lime	1929 1927 1919	93,114 tons 110,520 124,025	2,791,529 lb. 2,711,921 341,812	5,073,960 lb. 16,686,586 15,639,918	$2.00 2.00 1.88 100 lb.	$0.003 per lb.	Pulp and paper; textiles; wat purification; laundries
Colemanite, soda ash; natural brine; rasorite; ulexite	Colemanite and soda ash; evaporation of brine	1929 1927 1919	92,250 tons 64,864 29,635	..... 13,198 lb. 378	79,884 tons 36,953	2.74c. lb. 4.125 7.51	Refined: ½c. lb.	Enamel ware; glass; water softe ing; tanning; textiles; paper
Butyl alcohol, acetic acid	Esterification of butyl alcohol	1929 1927 1919	38,780,656 lb.[8] 26,304,343 ..... [8]n. and sec.	7,824,234 lb.		$1.28 1.515 gal.	7c. per lb.	Lacquers, enamels; pyroxyl compounds; perfumes, extract misc. solvents
Starch from corn; CO, CO_2, H_2; petroleum hydrocarbons	Corn fermentation; organic synthesis	1929 1927 1919	67,484,355 lb. 48,922,561 lb. (n)	..... 31,750		17.5c. lb. 19.0	6c. per lb.	Butyl acetate and lacquer s vents; solvent for film; plastic artificial leather; derivatives
Pyroligneous acid, milk of lime	Hardwood distillation	1929 1927 1919	58,072 tons 78,340 84,478	8,083 tons 3,447 Not shown	51 tons 5,817 8,181	$4.50 3.50 2.17 } Per 100 lb., bags	Crude: 2c. lb.	Acetic acid, acetone, acetate textiles
Lime, coke	Electric furnace reaction	1929 1927 1919	..... 201,955 tons	3,773,320 lb. 4,450,726	2,173 tons 2,436 11,950	5c. lb., drums 5 6.5	1c. lb.	Acetylene; cyanamid; acetic aci other organic compounds
Salt brines; lime and chlorine	Byproduct in Solvay sodium carbonate process; evaporation of brines	1929 1927 1919	282,749 tons 191,123 74,699	16,472,841 lb. 13,027,889	15,426 tons	$20.00 21.00 19.90 } ton, w'ks, fused	Crude: free	Laying dust; curing and harde ing cement, concrete; refriger tion
Sulphur, coke	Sulphur vapor on hot carbon; sulphur and carbon in electric furnace	1929 1927 1919	71,009,798 lb. 44,972,489 15,469,567			5c. lb., drums 5½ 6½	25%	Viscose rayon; carbon tetrachl ride; insecticides
Coke, limestone organic material	Combustion of carbon; fermentation; acid and limestone	1929 1927 1919	114,471,121 lb. 74,344,287 59,771,411			6c. lb. 8½ 11½	1c. lb. (on contents)	*Liquid*: Soft drinks; chemical fire extinguisher. *Solid*: R frigeration
Chlorine, carbon bisulphide	Chlorination of CS_2	1929 1927 1919	34,719,934 lb. 17,026,466 11,908,708			6½c. lb., drum 6½ 12½	1c. lb.	Solvent; fire extinguisher; clea er; chloroform
Sodium chloride	Electrolysis of NaCl	1929 1927 1919	[7] 241,295,383 lb. 180,163,438 34,392,000		7,168,000 lb.	3½c. 3.91 5½ } Lb. tank., liquid	25%	Pulp and paper; water puri cation; textiles; chemicals
Imported chromite; chromic iron ore	Chromite and mineral acid	1929 1927 1919	3,612,980 lb. 890,093	462,486 lb. 15,620		18½c. lb. 32	25%	Chromium plating; chemical d rivatives
			60 lb.	Not shown		46c. lb.	17c. lb.	Medicinal; nitrates; bro

CAL RAW MATERIALS FOR THE CESS INDUSTRIES

LS	MFG. PROCESSES	YEAR	PRODUCTION	IMPORTS	EXPORTS	AVERAGE PRICES	TARIFF (1930)	USES	NO.
e, pyroligide, alcohol	Calcium acetate and acid; organic synthesis; fermentation	1929 1927 1919	[1] 85,780,036 lb. 95,933,705 62,380,290	29,235,000 lb. 10,551,016 1,850,427	Not reported	$13.68 11.90 12.74 } Per 100 lb., 99% bbl.	1½c. per lb., 65% or less. 2c. per lb.—>65%	Acetates; acetic anhydride; textiles; lead pigments; leather	1
ropylene	Calcium acetate distillation; fermentation; organic synthesis	1929 1927 1919	[2] 35,276,549 lb. 6,045,914	68,703 lb. 266,223 240,223	7,897,000 lb. Not shown	13.8c. 12½ 15½ per lb. } Per lb. drums	20% ad valorem	Acetylene solvent; rayon; artificial leather; films; smokeless powder; lacq.; varnish removers	2
nd $(NH_4)_2$	Crystallization from sulphate mixture	1929 1927 1919	10,540,000 lb. 10,822,000 7,898,000	96,931 lb. 193,500 686,576 (incl. $Al_2(SO_4)_3$		3.25c. lb. 3.30 4.45	¼c. per lb.	Paper, leather, and textiles; medicine; baking powders	3
NaCl	Crystallization from $Al_2(SO_4)_3$ and NaCl solution	1929 1927 1919	34,504,000 lb. 38,908,000 Not shown	Not separately shown		3.40c. lb. 3.55 4.60	¼ to ½c. per lb.	Dyeing; tanning; color lakes; baking powders; medicine	4
rine, HCl	Chlorination of bauxite; Al + HCl	1929 1927 1919	35,102,000 lb. 34,260,000 9,612,000	Not shown	Not shown	5c. 15 $1.50 } Lb., anhydrous	25% n. s. p. f.	Petroleum refining; organic synthesis; carbonising wool; tanning	5
na; H_2SO_4	Bauxite or alumina hydrate and H_2SO_4	1929 1927 1919	347,089 tons 312,018 312,872	1,262 tons 766 110	26,588 tons 21,128	$1.40 1.40 1.70 } Per 100 lb., commerc.	¼ to ½c. per lb.	Water purification; paper; dyeing; tanning	6
gen and hy-	Coal processing; nitrogen fixation	1929 1927 1919	[3] 173,637,852 lb. 45,115,020 25,648,050	56 lb.	2,329,100 lb.	13c. lb. 12.5 35	2½c. per lb.	Refrigeration; fertilisers; nitric acid; organic preparations	7
); nitrogen	Coal processing; nitrogen fixation	1929 1927 1919	[3,4] 30,200,087 lb. 45,115,020 45,476,000	Not shown	Not shown	3c. 2.76 7.5 c. lb., c.l. drum, } Lb., 26°	25% Ad. val.	Fertilisers; anhydrous ammonia; textiles; rayon, rubber; pharmaceuticals	8
	Aqua ammonia and HCl; crystallization from NaCl and $(NH_4)_2SO_4$Sol.	1929 1927 1919	Not shown Not shown 13,212,619 lb.	9,561,000 lb. 14,279,000 2,011,028		4.6c. 5.5 11.8 } Lb., casks, white	2½c. lb.	Dry batteries; textile dyeing; soldering and galvanising; medicine	9
gen, hydro-	Coal processing; nitrogen fixation	1929 1927 1919	764,000 tons 620,500 288,800	19,052 tons 17,153 2,354	145,189 lb. 138,692	$2.20 2.40 4.42 } 100 lb., works	1½c. per lb.	Fertilisers; ammonium salts; fireproofing fabrics	10
l, fusel oil	Esterification of fusel oil; organic synthesis	1929 1927 1919	5,832,145 lb. 2,421,301 906,764	300 lb. 300		$1.75-2.00 2.16 3.70 } Gal. drums, tech.	7c. per lb.	Paints, lacquers; pyroxylin solvent; perfumes; flavoring extracts	11
d NaOH	Refining fusel oil; organic synthesis	1929 1927 1919	[5] 390,963 gal. 182,054 gal. 2,703,844 lb. 241,254 gal.	14,840 lb. 4,768 1,464,500		$1.90 2.50 4.05 } Gal., refined	6c. per lb.	Amyl acetate; organic synthesis; solvent	12
f copper and	Byproduct in ore extraction of metals	1929 1927 1919	11,123 tons 10,315 6,029	13,157 tons 12,517 4,389		4c. lb., kegs 6.5 9.5	Free	Insecticides; decolorising pot and tank glass; weed killers; cattle, sheep dips	13
um chloride;	Heating BaS with $CaCl_2$; treating witherite with HCl	1929 1927 1919	Not shown 3,334 tons 4,371	156,640 lb. 3,154,853 1,099,686		$63.50 ton 57.38 82.30	2c. per lb.	Pigments; barium chemicals; salt brine purification; leather, textiles	14
	Coal processing and tar distillation	1929 1927 1919	127,929,074 gal. 111,739,966 63,077,463	18,164,952 lb. 3,240,132 1,509,861	33,346,000 25,794,000 } Lb., crude 14,268,419 lb.	22.5c. lb., 90% 22.91 23.5	Free	Motor fuel; solvent, paint removers; organic chemicals	15
	Absorbing chlorine in slaked lime	1929 1927 1919	93,114 tons 110,520 124,025	2,791,529 lb. 2,711,921 341,812	5,073,960 lb. 16,686,586 15,639,918	$2.00 100 lb. 2.00 1.88	$0.003 per lb.	Pulp and paper; textiles; water purification; laundries	16
natural brine;	Colemanite and soda ash; evaporation of brine	1929 1927 1919	92,250 tons 64,864 29,635	..... 13,198 lb. 378	79,884 tons 36,953	2.74c. lb. 4.125 7.51	Refined: ½c. lb.	Enamel ware; glass; water softening; tanning; textiles; paper	17
acid	Esterification of butyl alcohol	1929 1927 1919	38,780,656 lb.[6] 26,304,343 ..... [6]n. and sec.	7,824,234 lb.		$1.28 gal. 1.515	7c. per lb.	Lacquers, enamels; pyroxylin compounds; perfumes, extracts; misc. solvents	18
O, CO_2, H_2; ma	Corn fermentation; organic synthesis	1929 1927 1919	67,484,355 lb. 48,922,561 lb. (n)	..... 31,750		17.5c. lb. 19.0	6c. per lb.	Butyl acetate and lacquer solvents; solvent for film; plastics, artificial leather; derivatives	19
k of lime	Hardwood distillation	1929 1927 1919	58,072 tons 78,340 84,478	8,083 tons 3,447 Not shown	51 tons 5,817 8,181	$4.50 3.50 2.17 } Per 100 lb., bags	Crude: 2c. lb.	Acetic acid, acetone, acetates; textiles	20
	Electric furnace reaction	1929 1927 1919	..... 201,955 tons	3,773,320 lb. 4,450,726	2,173 tons 2,436 11,950	5c. lb., drums 5 6.5	1c. lb.	Acetylene; cyanamid; acetic acid; other organic compounds	21
hlorine	Byproduct in Solvay sodium carbonate process; evaporation of brines	1929 1927 1919	282,749 tons 191,123 74,699	16,472,841 lb. 13,027,889	15,426 tons	$20.00 21.00 19.90 } ton, w'ks, fused	Crude: free	Laying dust; curing and hardening cement, concrete; refrigeration	22
	Sulphur vapor on hot carbon; sulphur and carbon in electric furnace	1929 1927 1919	71,009,798 lb. 44,972,489 15,469,567			5c. lb., drums 5½ 6½	25%	Viscose rayon; carbon tetrachloride; insecticides	23
ic material	Combustion of carbon; fermentation; acid and limestone	1929 1927 1919	114,471,121 lb. 74,344,287 59,771,411			6c. lb. 8½ 11½	1c. lb. (on contents)	*Liquid*: Soft drinks; chemicals; fire extinguisher. *Solid*: Refrigeration	24
phide	Chlorination of CS_2	1929 1927 1919	34,719,934 lb. 17,026,466 11,908,708			6½c. lb., drum 6½ 12½	1c. lb.	Solvent; fire extinguisher; cleaner; chloroform	25
	Electrolysis of NaCl	1929 1927 1919	[7] 241,295,383 lb. 180,163,438 34,392,000		7,168,000 lb.	3½c. 3.91 5½ } Lb. tank., liquid	25%	Pulp and paper; water purification; textiles; chemicals	26
chromic iron	Chromite and mineral acid	1929 1927 1919	3,612,980 lb. 890,093	462,486 lb. 15,620		18½c. lb. 32	25%	Chromium plating; chemical derivatives	27
						46c. lb.	17c. lb.	Medicinal citrates; beverages	28

CHEMICAL & METALLURGICAL ENGINEERING

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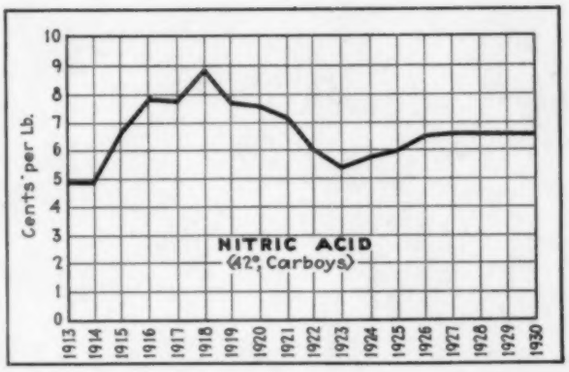
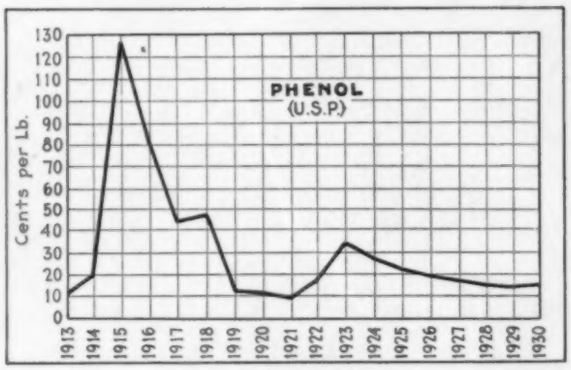
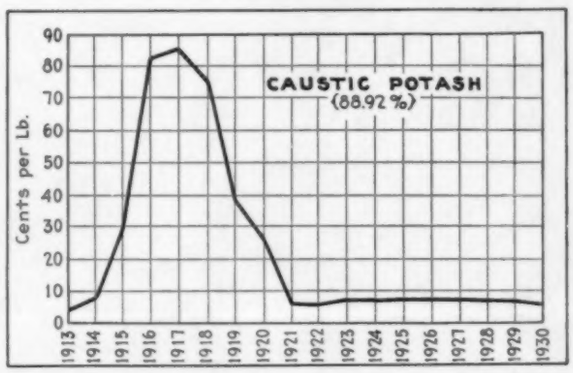
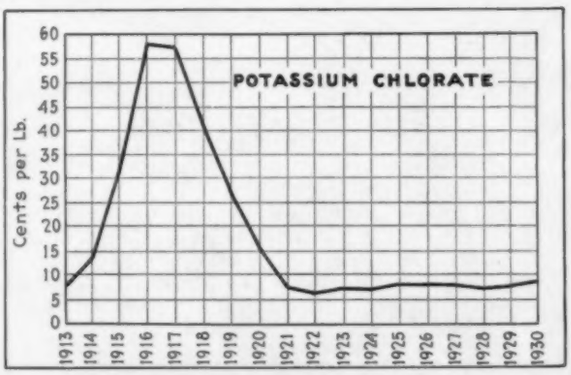
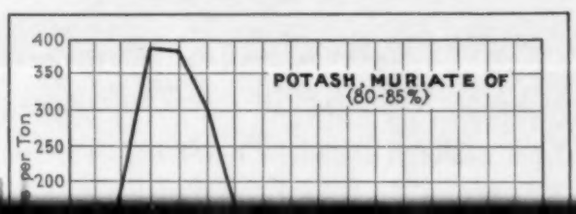
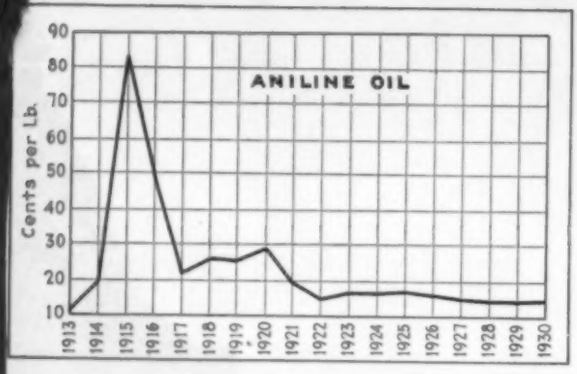


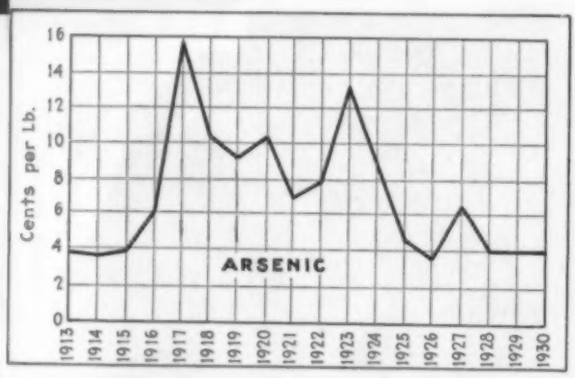


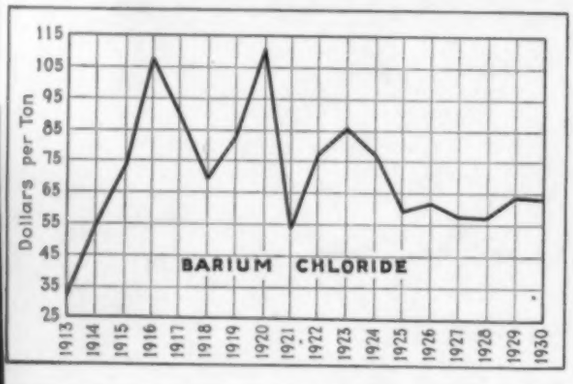


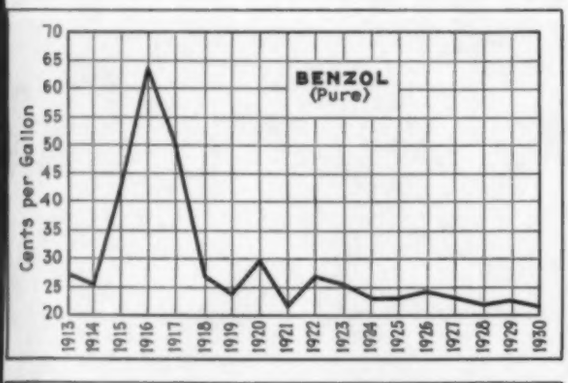


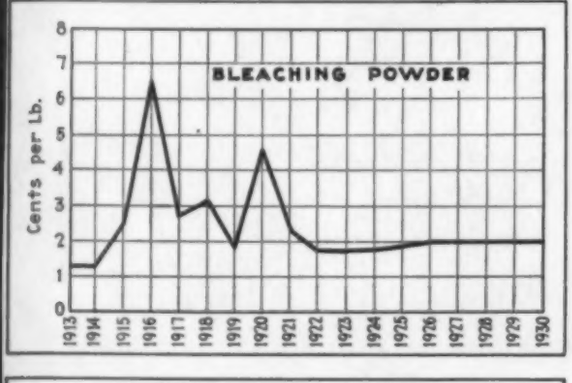


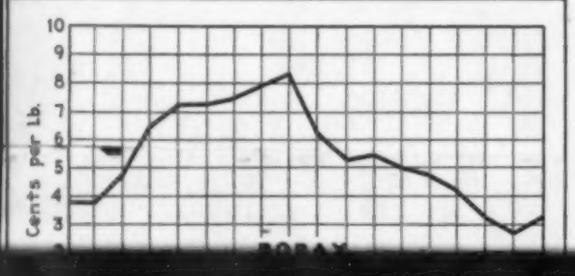












25	**Carbon Tetrachloride**	CCl_4	Technical; U. S. P.; C. P.
26	**Chlorine**	Cl_2	Technical
27	**Chromic Acid**	Cr_2O_3	Technical; pure: 98-99%
28	**Citric Acid**	$C_3H_4OH.(COOH)_3$	Technical; U. S. P.
29	**Copperas**	$FeSO_4.7H_2O$	Technical
30	**Copper Sulphate** (Blue Vitriol)	$CuSO_4.5H_2O$	Solid; crystalline
31	**Epsom Salts**	$MgSO_4.7H_2O$	Technical; U. S. P.
32	**Ethyl Acetate**	$CH_3COO\ C_2H_5$	Pure anhydrous; technical
33	**Ethyl Alcohol**	C_2H_5OH	Absolute (water free); cologne spirit; grain (95%); completely denatured; specially denatured
34	**Formaldehyde**	HCHO	Formalin (40% in H_2O); paraformaldehyde, 95%; U. S. P. (not under 37%)
35	**Glaubers Salts** (Sodium Sulphate)	$Na_2SO_4.10H_2O$	Crystals; anhydrous
36	**Hydrochloric Acid**	HCl	18, 20, and 22 deg. Bé; C. P., 100%
37	**Lactic Acid**	$CH_3CH(OH)COOH$	U. S. P., edible; 44% light, dark, 22% light, dark
38	**Lead Acetate** (Sugar of Lead)	$Pb(C_2H_3O_2)_2\ 3H_2O$	White crystals; brown grains
39	**Lead Carbonate** (White Lead)	$2PbCO_3.Pb(OH)_2$	Dry; ground in oil
40	**Lead, Red**	$2PbO.PbO_2$	Dry; in oil
41	**Lime**	CaO	Chemical
42	**Litharge**	PbO	Flake; yellow; buff (levigated)
43	**Methanol**	CH_3OH	95%; 97% synthetic; anti-freeze (76½%)
44	**Naphthalene**	$C_{10}H_8$	Flakes, balls, etc.; crude; U. S. P.; C. P.
45	**Nitric Acid**	HNO_3	36, 38, and 40 deg. Bé., 100%; C. P.
46	**Orange Mineral**	Pb_3O_4	Technical
47	**Oxalic Acid**	$(COOH)_2\ 2H_2O$	Technical; crystals
48	**Phenol**	C_6H_5OH	U. S. P., natural, synthetic
49	**Phosphoric Acid**	H_3PO_4	U. S. P.; 50% technical
50	**Potassium Bichromate**	$K_2Cr_2O_7$	C. P., crystals
51	**Potassium Bitartrate**	$KHC_4H_4O_6$	
52	**Potassium Carbonate**	K_2CO_3	Refined; crude
53	**Potassium Chlorate**	$KClO_3$	Technical; C. P. crystals, powder
54	**Potassium Chloride**	KCl	80%
55	**Potassium Hydroxide**	KOH	Technical; C. P.
56	**Potassium Permanganate**	$KMnO_4$	U. S. P.
57	**Potassium Prussiate**	$K_4Fe(CN)_6.3H_2O$	Yellow; technical
58	**Pyrites**	FeS_2	Ore with 40-50% sulphur, lumps or fines, varying copper content
59	**Salt Cake**	Na_2SO_4	Technical

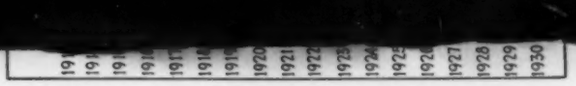
				59,771,411			11¾		
C. P.	Chlorine, carbon bisulphide	Chlorination of CS_2	1929 1927 1919	34,719,934 lb. 17,026,466 11,908,708			6½c. lb., drum 6¾ 12¼	1c. lb.	Solvent; fire er; chloroform
	Sodium chloride	Electrolysis of NaCl	1929 1927 1919	[7] 241,295,383 lb. 180,163,438 34,392,000		7,168,000 lb.	3½c. 3.91 5½ } Lb. tank., liquid	25%	Pulp and pa cation; textil
99%	Imported chromite; chromic iron ore	Chromite and mineral acid	1929 1927 1919	3,612,980 lb. 890,093	462,486 lb. 15,620		18½c. lb. 32	25%	Chromium pl rivatives
	Calcium citrate, cane sugar, H_2SO_4	Citrate and heavy acids; sugar fermentation	1929 1927 1919	10,697,660 lb. 7,058,215 3,163,676	Not shown 117,000 lb. 1,224,591		46c. lb. 44.33c. lb. $1.05	17c. lb.	Medicinal ci foods
	Byproduct in pickling metal	Evaporation of pickling solution	1929 1927 1919	56,846 61,527 } Tons for sale 59,383	650,094 lb. 805,956	..... Not available	$13.00 ton 13.00 25.20	Free	Water purifi ments; dyein
	H_2SO_4—copper or copper oxide	Leaching spent pyrites; byproduct in electro. copper refining	1929 1927 1919	79,187,343 lb. 56,666,812 35,287,881	5,388,743 lb. 1,978,726 16,545	6,420,000 lb. 6,206,904 9,140,673	$5.94,100 lb. 4.91 7.87	Free	Fungicide; sto pigments; w plating; med
	Magnesite, dolomite, H_2SO_4; natural brines	H_2SO_4 and minerals; crystallizing brines	1929 1927 1919	36,983 tons 27,665 29,384	12,083,000 lb. 11,856,800 17,647	695,173 lb. 11,620,675 17,647	$2.15 1.92 3.65 } 100 lb., U.S.P.	½c. lb.	Textiles; pape
hnical	Ethyl alcohol, acetic acid, fused sodium acetate, H_2SO_4	Ethyl alcohol and acetic acid or sodium acetate; oxidation of ethyl alcohol	1929 1927 1919	73,895,640 49,203,156 } Lb. (85%) 5,780,549	..... 3,748 lb.		99.6c. $1.12 1.27 } Gal., 50 gal., drum	3c. lb.	Solvent for py artifical fruit solvent
; cologne spirit; pletely dena- natured	Blackstrap molasses, grain, ethylene	Fermentation, organic synthesis	1929 1927 1919	[6] 106,960,458 95,448,676 } Gal., wine 38,270,939	*60,492 gal. 162,669 ..... *pure denat.	..... 477,089 gal.	48c. gal. 38.4	15c. gal.	Anti-freeze; so plastics, etc. dyes; chemic
H_2O); parafor- U. S. P. (not	Methanol, copper gauze	Air and methanol over hot copper gauze	1929 1927 1919	51,786,422 lb. 29,920,072 25,006,815	19,545 lb. (solid) 502	2,588,000 lb. 2,235,960	9.08c. lb., 40% 9.98 21.8	Formalin—1¼c. lb. Paraform—8c. lb. Hex'm. tetram., 11c. lb.	Phenolic resi accelerators; fectant; reduc
	Natural brine; salt cake	Crystallised from brines; refining salt cake	1929 1927 1919	59,021 tons 53,420 42,206	..... 5,377 tons	1,666 tons	$1.10—100 lb., wks. 1.05 1.35	$1.00 per ton	Dyes; textile medicine; ca
B6; C. P.,	Sodium chloride, sulphuric acid, niter cake; hydrogen, chlorine	NaCl and niter cake or H_2SO_4; Chlorination of organics; direct synthesis	1929 1927 1919	254,936 tons 224,593 221,749	[7]83 lb.		$1.10—100 lb. 1.00—18 deg. B6. 1.75	Free	Chlorides an pickling iro dyes; soap; g
% light, dark,	Starch, molasses, or waste carbohydrates	Fermentation	1929 1927 1919	Not shown	404,315 lb. 539,227 11,023		11½c. 13 13½ } Lb., bbls., 44% light	2c. lb.: < 30% 4c. lb.: >30% <55% 9c. lb.: > 55%	Tanning; dy bakery produ
n grains	Acetic acid, litharge; pyroligneous acid	Acetic acid and litharge	1929 1927 1919	Not shown 3,016,840 lb. 5,131,133	385,331 lb. (all) 238,402 lb. (all) 234 lb. (white)		12.91c. lb., brown 12.17 13.18	2½c. lb., white 2c. lb., brown, gray, yellow	Pigments; dye cine; insecti
	Acetic acid, tan bark, cast lead, CO_2	*Dutch:* Lead and acetic acid, in tan bark; *Quick:* Atomized lead heated with CO_2 and acetic acid	1929 1927 1919	297,612,497 331,617,056 } Lb., dry 262,959,465	196,478 lb. 330,421 Not available	11,815,000 lb. 12,094,514 28,033,485	8½c. lb., dry 9½ 9¼	2½c. lb.	Paints; putty pounds
	Metallic lead; litharge	Molten lead oxidised in steps	1929 1927 1919	86,042,000 lb. 78,146,000 64,724,000	10,197 lb. 51,688 7,199	[8]5,780,147 lb. 2,857,581 7,952,730	10.21c. lb., dry 10.13 15.7	2½c. lb.	Metal paint; age batteries
	Limestone; shells	Burning	1929 1927 1919	2,290,612 tons 1,943,199 [10] 1,600,000	32,848 tons 27,652 8,353	17,334 tons 15,488 6,800	$7.33 ton, works 7.94 4.25	10c. per 100 lb.	Metallurgy; water purific
levigated)	Metallic lead	Lead oxidised in reverberatory furnace; byproduct in making lead bullion	1929 1927 1919	175,832,000 lb. 163,310,000 93,478,000	3,763 lb. 1,182		9.2c. 9.3 9.6 } Lb. casks, powder	2½c. lb.	Glass, potter driers; lead
ic; anti-freeze	Carbon monoxide, hydrogen; hardwood	Synthesis; hardwood distillation	1929 1927 1919	8,355,189 8,008,838 } gal., crude 9,103,996 gal.	538,427 gal. 1,710,470	498,000 gal. 311,000 718,427	57½c. gal., 95% 64.9c. $1.26	18c. gal.	Formaldehyde naturant for dyes; plastics
ude; U. S. P.;	Coal tar and gas	Coal products refining	1929 1927 1919	31,143,716 lb. 53,176,660 20,114,243	32,417,444 lb. 6,420,347 3,591,168		4½c. 4.58 8.1 } Lb., bbl., flake	Crude: free Refined: 40% Ad val., and 7c. lb.	Dyes; insect chemicals; ru leather; wood
., 100%; C. P.	Sodium nitrate, sulphuric acid; Ammonia	Sodium nitrate and H_2SO_4 in retort; ammonia oxidation	1929 1927 1919	156,313 tons 121,991 86,992	..... 36,508 lb.	.... 737,273 lb.	6½c. lb., 40° 6¾ 7.58	Free	Explosives; roxylin); dy phuric acid
	White lead	Heating white lead in air	1929 1927 1919	1,356,000 lb. 1,418,000	52,122 lb. 44,866 39,781		12.19c. lb 12.23	3c. lb.	Pigment; print
	Carbon monoxide, caustic soda, lime, H_2SO_4	Heating sodium formate (from CO and NaOH)	1929 1927 1919	Not shown Not shown 1922—3,973,000 lb.	1,346,608 1,843,732 651,690		11.04c. 11 26.5 } Lb., crystals	6c. lb.	Laundries; tex ing; leather,
thetic	Coal tar; benzene, caustic soda	Distillation; sulphonating or chlorinating benzene	1929 1927 1919	24,177,618 lb. 8,041,082 1,543,659	432,266 lb.* 206,500 ..... *6 mos.		13.89c. lb., U.S.P. 16.67 12.33	20% ad val. and 3½c. lb.	Synthetic resin explosives; graphic chem
cal	Phosphate rock, H_2SO_4	Heat reduction of calcium phosphate and oxidation; H_2SO_4 and phosphate	1929 1927 1919	29,895,470 lb. 22,397,366 [11] 22,109,302	226,819 637,412 10,925	Not available	8½c. 7½ 25 } Lb., carb., 50% tech.	2c. lb.	Fertilisers; ph ture; rustpr sugar; peroxi
	Chromic ores, potash, lime, H_2SO_4	Oxidation to chromate, acidified with H_2SO_4, crystalized	1929 1927 1919	..... Not available Not available	..... 5,007 lb. 15,450		8½c. lb., casks 8½ 29½	2½c. lb.	Chrome tann ments; textil ing fats; oxid
	Argols; wine lees	Crystallized from solution	1929 1927 1919	7,432,559 lb. 7,594,777 4,854,550	181,000 lb. 291,000 23,652		26.7c. lb. 25½ 57½	5c. lb.	Baking powd dyeing; meta salts; pharm
	Distillery waste; Stassfurt salts (import)	Carbonising and leaching molasses wastes	1929 1927 1919	Not available Not available (Cr.) 48,664,478 lb.	22,644,034 13,192,395 } lb. (ref.) 561,013	50,000 lb. 25,000 Not available	5½c. 5.44 20.25 } Lb., 80-85% calc.	½c. lb.	Soft soaps; g dyeing
tals, powder	Potassium chloride	Electrolysis	1929 1927 1919		13,033,403 lb. 13,122,384 199,077	.... 1,903,133 lb.	7.58c. Lb., powder 7.8 26.41	1½c. lb.	Matches, fire dyeing; toot
	Sylvite, carnallite, natural brines	Fractional crystallization	1929 1927 1919	[12] 107,800 tons 76,819 116,634	230,966 tons 163,817 20,716		$36.63 ton, 80% 36.40 162.00	Free	Fertilizer; c electrolysis
	Potassium chloride, potash brine	Electrolysis	1929 1927 1919	14,392,000 lb. Not shown 8,358,834	15,642,419 lb. 14,759,060 466,620		6½c. lb. 7.2 39.2	1c. lb.	Soft soap; pot ate; dyes
	Potassium hydroxide, manganese ore, H_2SO_4, chlorine	Fused ore oxidized with Cl or electrolitically	1929 1927 1919	Not shown	33,709 lb. 319,332 4,000		16c. lb. 14.13 59.16	6c. lb.	Lithopone; a ing; textiles;
	Spent oxide from gas purification; KCl, lime, K_2CO_3	Oxide treated with lime and potash salts	1929 1927 1919	Not available	113,480 lb. 159,250 515,236		19½c. 18 46 } Lb., casks, N. Y.	4c. lb.	Prussian blu case-hardeni ferricyanides
phur, lumps or r content			1929 1927 1919	333,465 [13] 302,826 420,647	514,336 250,794 } All tons = 388,973 } 2240 lb.		13c. per unit 12½ 17	Free	Sulphuric aci for paper ind
	Salt, H_2SO_4; natural brines	Byproduct in HCl manufacture; evaporating brines	1929 1927	217,626 tons 208,565	91,645 tons 11,171		$17.74 ton 20.10	Free	Kraft paper; phide; Glaub

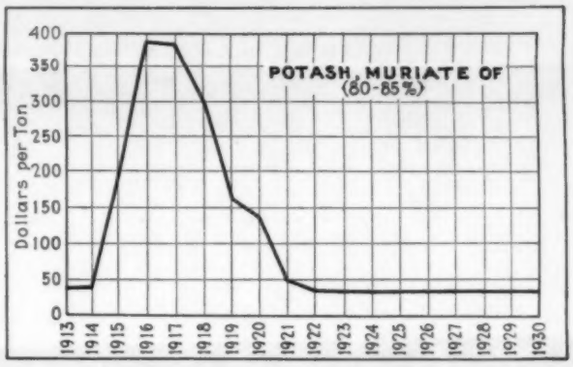
		1919	59,771,411			11½	
Chlorine, carbon bisulphide	Chlorination of CS_2	1929 1927 1919	34,719,934 lb. 17,026,466 11,908,708			c. lb., drum 6¾ 12½	1c. lb.
Sodium chloride	Electrolysis of NaCl	1929 1927 1919	[7] 241,295,383 lb. 180,163,438 34,392,000		7,168,000 lb.	3½c. 3.91 5½ } Lb. tank., liquid	25%
Imported chromite; chromic iron ore	Chromite and mineral acid	1929 1927 1919	3,612,980 lb. 890,093	462,486 lb. 15,620		18½c. lb. 32	25%
Calcium citrate, cane sugar, H_2SO_4	Citrate and heavy acids; sugar fermentation	1929 1927 1919	10,697,660 lb. 7,058,215 3,163,676	Not shown 117,000 lb. 1,224,591		46c. lb. 44.33c. lb. $1.05	17c. lb.
Byproduct in pickling metal	Evaporation of pickling solution	1929 1927 1919	56,846 61,527 } Tons for sale 59,383	650,094 lb. 805,956	..... Not available	$13.00 ton 13.00 25.20	Free
H_2SO_4—copper or copper oxides	Leaching spent pyrites; byproduct in electro. copper refining	1929 1927 1919	79,187,343 lb. 56,666,812 35,287,881	5,388,743 lb. 1,978,726 16,545	6,420,000 lb. 6,206,904 9,140,673	$5.94,100 lb. 4.91 7.87	Free
Magnesite, dolomite, H_2SO_4; natural brines	H_2SO_4 and minerals; crystallising brines	1929 1927 1919	36,983 tons 27,665 29,384	12,083,000 lb. 11,856,800 17,647	695,173 lb. 11,620,675 17,647	$2.15 1.92 3.65 } 100 lb., U.S.P.	¼c. lb.
Ethyl alcohol, acetic acid, fused sodium acetate, H_2SO_4	Ethyl alcohol and acetic acid or sodium acetate; oxidation of ethyl alcohol	1929 1927 1919	73,895,640 49,203,156 } Lb. (85%) 5,780,549	..... 3,748 lb.		99.6c. $1.12 1.27 } Gal., 50 gal., drum	3c. lb.
Blackstrap molasses, grain, ethylene	Fermentation, organic synthesis	1929 1927 1919	[8] 106,960,458 95,448,676 } Gal., wine 38,270,939	*60,492 gal. 162,669 ..... *pure denat.	..... 477,089 gal.	48c. gal. 38.4	15c. gal.
Methanol, copper gauze	Air and methanol over hot copper gauze	1929 1927 1919	51,786,422 lb. 29,920,072 25,006,815	19,545 lb. (solid) 502	2,588,000 lb. 2,235,960	9.08c. lb., 40% 9.98 21.8	Formalin—1¼c. lb. Paraform—8c. lb. Hex'm. tetram., 11c. lb.
Natural brine; salt cake	Crystallised from brines; refining salt cake	1929 1927 1919	59,021 tons 53,420 42,206	..... 5,377 tons	1,666 tons	$1.10—100 lb., wks. 1.05 1.35	$1.00 per ton
Sodium chloride, sulphuric acid, niter cake; hydrogen, chlorine	NaCl and niter cake or H_2SO_4; Chlorination of organics; direct synthesis	1929 1927 1919	254,936 tons 224,593 221,749	[7]83 lb.		$1.10—100 lb. 1.00—18 deg. Bé. 1.75	Free
Starch, molasses, or waste carbohydrates	Fermentation	1929 1927 1919	Not shown	404,315 lb. 539,227 11,023		11½c. 13 13½ } Lb., bbls., 44% light	2c. lb.: < 30% 4c. lb.: >30% <55% 9c. lb.: > 55%
Acetic acid, litharge; pyroligneous acid	Acetic acid and litharge	1929 1927 1919	Not shown 3,016,840 lb. 5,131,133	385,331 lb. (all) 238,402 lb. (all) 234 lb. (white)		12.91c. lb., brown 12.17 13.18	2½c. lb., white 2c. lb., brown, gray, yellow
Acetic acid, tan bark, cast lead, CO_2	*Dutch:* Lead and acetic acid, in tan bark; *Quick:* Atomised lead heated with CO_2 and acetic acid	1929 1927 1919	297,612,497 331,617,056 } Lb., dry 262,959,465	196,478 lb. 330,421 Not available	11,815,000 lb. 12,094,514 28,033,485	8½c. lb., dry 9½ 9½	2½c. lb.
Metallic lead; litharge	Molten lead oxidised in steps	1929 1927 1919	86,042,000 lb. 78,146,000 64,724,000	10,197 lb. 51,688 7,199	[9]5,780,147 lb. 2,857,581 7,952,730	10.21c. lb., dry 10.13 15.7	2½c. lb.
Limestone; shells	Burning	1929 1927 1919	2,290,612 tons 1,943,199 [10] 1,600,000	32,848 tons 27,652 8,353	17,334 tons 15,488 6,800	$7.33 ton, works 7.94 4.25	10c. per 100 lb.
Metallic lead	Lead oxidised in reverberatory furnace; byproduct in making lead bullion	1929 1927 1919	175,832,000 lb. 163,310,000 93,478,000	3,763 lb. 1,182		9.2c. 9.3 9.6 } Lb. casks, powder	2½c. lb.
Carbon monoxide, hydrogen; hardwood	Synthesis; hardwood distillation	1929 1927 1919	8,355,189 8,008,838 } gal., crude 9,103,996 gal.	538,427 gal. 1,710,470	498,000 gal. 311,000 718,427	57½c. gal., 95% 64.9c. $1.26	18c. gal.
Coal tar and gas	Coal products refining	1929 1927 1919	31,143,716 lb. 53,176,660 20,114,243	32,417,444 lb. 6,420,347 3,591,168		4½c. 4.58 8.1 } Lb., bbl., flake	Crude: free Refined: 40% Ad val., and 7c. lb.
Sodium nitrate, sulphuric acid; Ammonia	Sodium nitrate and H_2SO_4 in retort; ammonia oxidation	1929 1927 1919	156,313 tons 121,991 86,992	..... 36,508 lb.	.... 737,273 lb.	6½c. lb., 40° 6¾ 7.58	Free
White lead	Heating white lead in air	1929 1927 1919	1,356,000 lb. 1,418,000	52,122 lb. 44,866 39,781		12.19c. lb 12.23	3c. lb.
Carbon monoxide, caustic soda, lime, H_2SO_4	Heating sodium formate (from CO and NaOH)	1929 1927 1919	Not shown Not shown 1922—3,973,000 lb.	1,346,608 1,843,732 651,690		11.04c. 11 26.5 } Lb., crystals	6c. lb.
Coal tar; benzene, caustic soda	Distillation; sulphonating or chlorinating benzene	1929 1927 1919	24,177,618 lb. 8,041,082 1,543,659	432,266 lb.* 206,500 ..... *6 mos.		13.89c. lb., U.S.P. 16.67 12.33	20% ad val. and 3½c. lb.
Phosphate rock, H_2SO_4	Heat reduction of calcium phosphate and oxidation; H_2SO_4 and phosphate	1929 1927 1919	29,895,470 lb. 22,397,366 [11] 22,109,302	226,819 637,412 10,925	Not available	8½c. 7½ 25 } Lb., carb., 50% tech.	2c. lb.
Chromic ores, potash, lime, H_2SO_4	Oxidation to chromate, acidified with H_2SO_4, crystalised	1929 1927 1919	..... Not available Not available	..... 5,007 lb. 15,450		8½c. lb., casks 8½ 29½	2½c. lb.
Argols; wine lees	Crystallised from solution	1929 1927 1919	7,432,559 lb. 7,594,777 4,854,550	181,000 lb. 291,000 23,652		26.7c. lb. 25½ 57½	5c. lb.
Distillery waste; Stassfurt salts (imp't)	Carbonising and leaching molasses wastes	1929 1927 1919	Not available Not available (Cr.) 48,664,478 lb.	22,644,034 13,192,395 } lb. (ref.) 561,013	50,000 lb. 25,000 Not available	5½c. 5.44 20.25 } Lb., 80-85% calc.	¼c. lb.
Potassium chloride	Electrolysis	1929 1927 1919		13,033,403 lb. 13,122,384 199,077	.... 1,903,133 lb.	7.58c. Lb., powder 7.8 26.41	1½c. lb.
Sylvite, carnallite, natural brines	Fractional crystallisation	1929 1927 1919	[12] 107,800 tons 76,819 116,634	230,966 tons 163,817 20,716		$36.63 ton, 80% 36.40 162.00	Free
Potassium chloride, potash brine	Electrolysis	1929 1927 1919	14,392,000 lb. Not shown 8,358,834	15,642,419 lb. 14,759,060 466,620		6½c. lb. 7.2 39.2	1c. lb.
Potassium hydroxide, manganese ore, H_2SO_4, chlorine	Fused ore oxidised with Cl or electrolitically	1929 1927 1919	Not shown	33,709 lb. 319,332 4,000		16c. lb. 14.13 59.16	6c. lb.
Potash oxide from gas purification; KCl, lime, K_2CO_3	Oxide treated with lime and potash salts	1929 1927 1919	Not available	113,480 lb. 159,250 515,236		19½c. 18 46 } Lb., casks, N. Y.	4c. lb.
		1929 1927 1919	333,465 [13] 302, 420,6	514,336	All tons	13c. per unit 17	Free

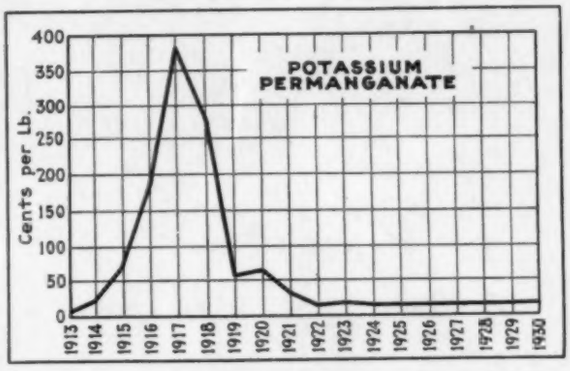
ENGINEERING

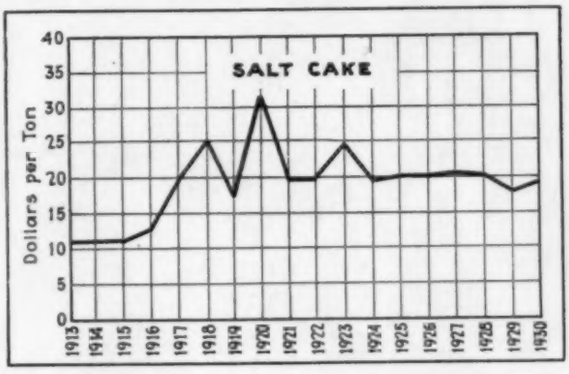
55	Potassium hydroxide	KOH	Technical; C. P.		In effect.

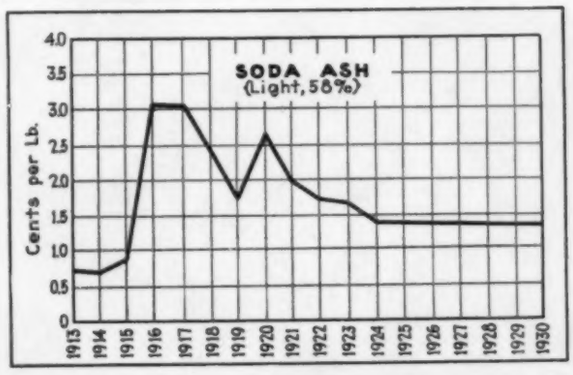
	frigeration	
	Solvent; fire extinguisher; cleaner; chloroform	25
	Pulp and paper; water purification; textiles; chemicals	26
	Chromium plating; chemical derivatives	27
	Medicinal citrates; beverages; foods	28
	Water purification; inks, pigments; dyeing; chemicals	29
	Fungicide; storage batteries; dyes, pigments; wood preservative; plating; medicines	30
	Textiles; paper, leather; medicine	31
	Solvent for pyroxylin compounds; artifical fruit essences; general solvent	32
l.	Anti-freeze; solvents for laquers, plastics, etc.; pharmaceuticals; dyes; chemicals	33
in—1½c. lb. m—8c. lb. tetram., 11c. lb.	Phenolic resins; indigo; rubber accelerators; antisepetic disinfectant; reducing agent	34
per ton	Dyes; textiles; glass; tanning; medicine; cattle feed; pigments	35
	Chlorides and other chemicals; pickling iron; glue; textiles; dyes; soap; glucose	36
: < 30% .: > 30% < 55% : > 55%	Tanning; dyeing mordants; bakery products; foodstuffs	37
., white ., brown, gray,	Pigments; dyeing mordants; medicine; insecticides	38
.	Paints; putty; glazes; lead compounds	39
.	Metal paint; rubber goods; storage batteries; pipe fitting; glass	40
r 100 lb.	Metallurgy; refractories; paper; water purification; glass; leather	41
.	Glass, pottery; rubber; paints, driers; lead acetate, other salts	42
l.	Formaldehyde; anti-freeze; denaturant for alcohol; solvent; dyes; plastics, rubber	43
: free d: 40% ., and 7c. lb.	Dyes; insecticide; Explosives; chemicals; rubber goods; candles; leather; wood preserving	44
	Explosives; nitrocellulose (pyroxylin); dyes; nitrates; sulphuric acid chamber process	45
	Pigment; printing ink	46
	Laundries; textile coloring; bleaching; leather, wood; metal polishes	47
d val. and 3½c.	Synthetic resins; germicide; dyes; explosives; tanning; photographic chemicals	48
	Fertilizers; phosphate manufacture; rustproofing; beverages; sugar; peroxide	49
b.	Chrome tanning; chrome pigments; textile coloring; bleaching fats; oxidising	50
	Baking powders; candy; wool dyeing; metal polishes; Rochelle salts; pharmaceuticals	51
	Soft soaps; glass; dyeing; wool dyeing	52
b.	Matches, fire works, explosives; dyeing; tooth paste; medicine	53
	Fertilizer; caustic potash by electrolysis	54
.	Soft soap; potassium permanganate; dyes	55
.	Lithopone; antiseptics; bleaching; textiles; carbon dioxide	56
.	Prussian blue; textile dyeing; case-hardening iron; cyanides, ferricyanides	57
	Sulphuric acid; sulphur dioxide for paper industry	58

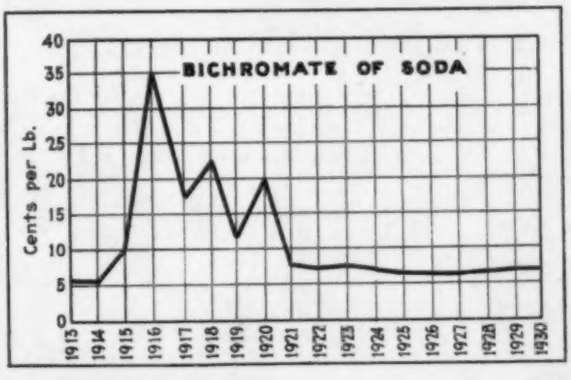


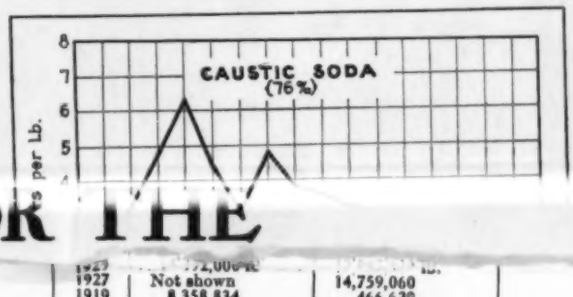










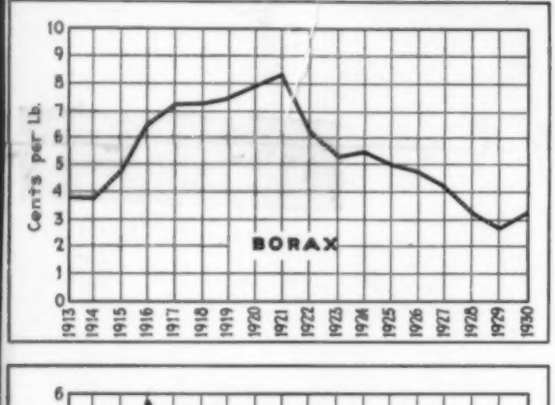


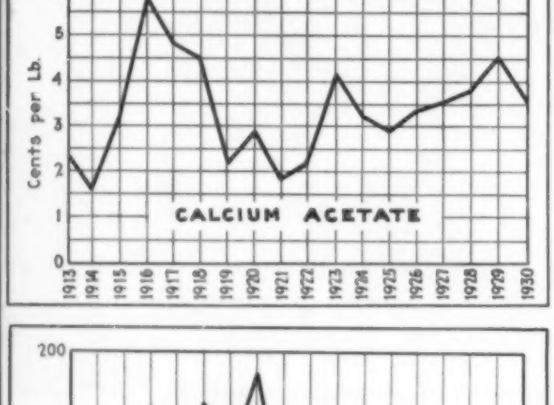
FOR THE

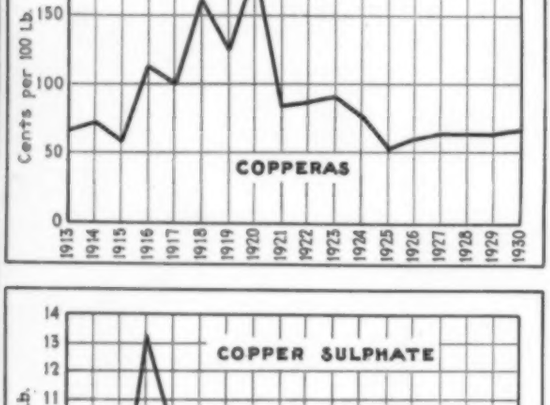
	1919		515,256		
	1929	333,465	514,336	All tons	13c. per unit	Free
	1927	[13]302,[illegible]	[illegible]		
	1919	420,6[illegible]			

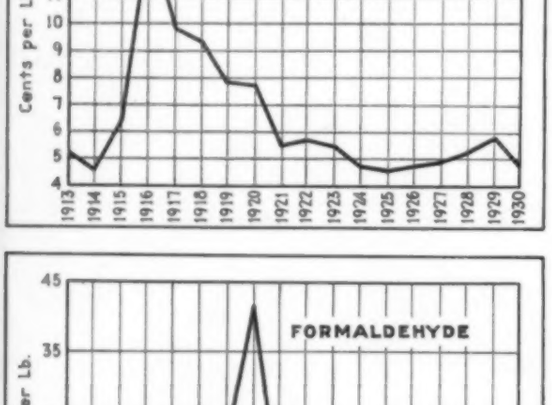
55	**Potassium Hydroxide**	KOH	Technical; C. P.	In chlor
56	**Potassium Permanganate**	$KMnO_4$	U. S. P.	Potassium hydroxid ore, H_2SO_4, chlorine
57	**Potassium Prussiate**	$K_4Fe(CN)_6.3H_2O$	Yellow; technical	Spent oxide from ga KCl, lime, K_2CO_3
58	**Pyrites**	FeS_2	Ore with 40-50% sulphur, lumps or fines, varying copper content	
59	**Salt Cake**	Na_2SO_4	Technical	Salt, H_2SO_4; natural
60	**Soda Ash**	Na_2CO_3	Light / Dense } 58% Na_2O	Salt, ammonia, lime, brine
61	**Sodium Acetate**	$CH_3COONa.3H_2O$	Technical, U.S.P.; fused, recrystallised	Pyroligneous acid, soc sulphate
62	**Sodium Bicarbonate**	$NaHCO_3.nH_2O$	Technical, refined	Salt brine, limeston coal
63	**Sodium Bichromate**	$Na_2Cr_2O_7.2H_2O$	Technical	Chromic ore, soda as H_2SO_4
64	**Sodium Bisulphate**	$NaHSO_4$	Technical	Sodium nitrate, H_2S
65	**Sodium Chlorate**	$NaClO_3$	Technical; refined, crystals	Sodium chloride
66	**Sodium Chloride**	NaCl	Crude rock; refined table; technical	Natural brine; miners
67	**Sodium Fluoride** (Fluoral)	Na_2F_2	Technical, 96-98%	Soda ash, hydrofluoric
68	**Sodium Hydroxide** (Caustic Soda)	NaOH	60, 70, 74, 76% Na_2O; solid, fused: 50% sol.	Sodium chloride, soda
69	**Sodium Nitrate**	$NaNO_3$	Fertiliser: 91-95%; refined: 96-97%	Chile saltpeter; soda thetic nitric acid
70	**Sodium Nitrite**	$NaNO_2$	Purity: 96-98%	Ammonia, soda ash; s
71	**Sodium Phosphates**	Na_3PO_4	Mono—NaH_2PO_4 Di—Na_2HPO_4 Tri—Na_3PO_4	Phosphoric acid, soda dium hydroxide
72	**Sodium Silicate**	$Na_2O.3SiO_2$	30, 40 deg. Bé. sols.; solid, fused	Sand, soda ash
73	**Sodium Sulphide**	Na_2S	Crystal: 30%; fused: 60%	Barium sulphide, salt
74	**Sodium Sulphate**—See	Sodium Bisulph	ate, Salt Cake, Glaubers Salts	
75	**Sodium Sulphite**	$Na_2SO_3.7H_2O$	Crystals; dry powder	Soda ash, SO_2 or sodiu
76	**Sulphur**	Sn	Crude, refined, flowers; roll, pr cipitated, pure, U. S. P.	Mineral; coal gas
77	**Sulphur Chlorides**	$S_2Cl_2.SCl_2$	Yellow; red	Chlorine, sulphur
78	**Sulphur Dioxide**	SO_2	Commercial; liquid	Brimstone; pyrites; sm
79	**Sulphuric Acid**	H_2SO_4	50, 60, 66 deg. Bé.; 98-100% oleum	Sulphur; iron pyrites; s gases
80	**Tartaric Acid**	$(CHOH)_2.(COOH)_2$	Powder, crystal, granite	Argols, wine lees; calci H_2SO_4
81	**Zinc Chloride**	$ZnCl_2.nH_2O$	Granular, fused; tablets, solutio	Zinc or zinc ore, hydro
82	**Zinc Oxide**	ZnO	Lead-free: Not < 99% Zn leaded: 3-25% lead sulphi ground, dry and in oil	Zinc ore, coal
83	**Zinc Sulphate**	$ZnSO_4.7H_2O$	Technical; refined: 99.5% crys salt	Zinc scrap and ores, H

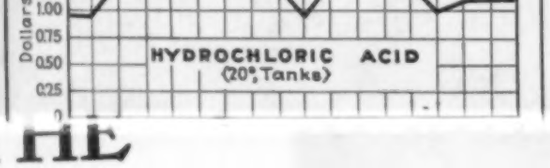
[1] Total dilute and glacial (except fermentation) incl. acetic anhydride. [2] Commercial Solvents Co. only. textile industry. [3] Total for denatured alcohol by fiscal years. [9] Includes litrge. [10] Total for chemic

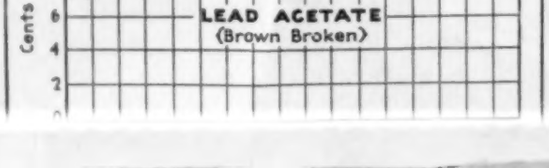








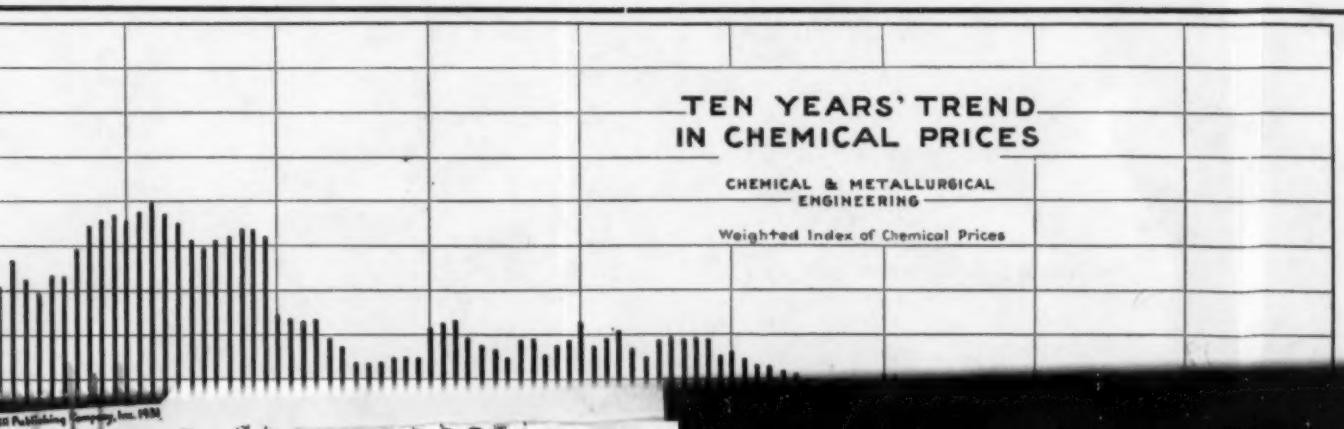


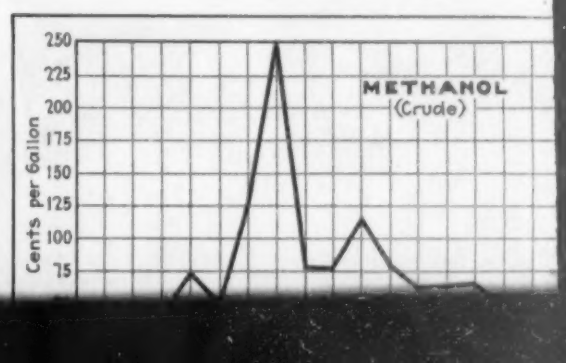


OR THE

...m hydroxide, manganese SO_4, chlorine	Fused ore oxidised with Cl or electrolitically	1929 1927 1919	Not shown	33,709 lb. 319,332 4,000		16c. lb. 14.13 59.16	6c. lb.	Lithopone; antiseptics; bleaching; textiles; carbon dioxide	5
...xide from gas purification; ...me, K_2CO_3	Oxide treated with lime and potash salts	1929 1927 1919	Not available	113,480 lb. 159,250 515,236		19½c. } Lb., casks, 18 } N. Y. 46	4c. lb.	Prussian blue; textile dyeing; case-hardening iron; cyanides, ferricyanides	5
		1929 1927 1919	333,465 [12]302,826 420,647	514,336 } All tons 250,794 } = 388,973 } 2240 lb.		13c. per unit 12½ 17	Free	Sulphuric acid; sulphur dioxide for paper industry	8
...SO_4; natural brines	Byproduct in HCl manufacture; evaporating brines	1929 1927 1919	217,626 tons 208,565 179,003	91,645 tons 11,171 28		$17.74 ton 20.10 17.24	Free	Kraft paper; glass; sodium sulphide; Glaubers salt	5
...mmonia, lime, coal; natural	Ammonia-soda; electrolysis; evaporating brines	1929 1927 1919	2,682,216 tons 2,037,808 1,390,628	14,355 tons 99,372 lb. 829,266 lb.	77,913,247 lb. 40,802,301 100,961,927	$1.32 —100 lb. 1.325 1.74	½c. lb.	Glass; soap; chemicals; pulp and paper; water softening; petroleum refining	6
...neous acid, soda ash, sodium ...te	Neutralising acetic acid and recrystallising	1929 1927 1919	592,253 lb. 1,854,588 2,260,459	874,895 lb. 1,113,262		5½c. lb., bbl. 4½ 8½	25%	For glacial acetic acid and acetic anhydride; in dyes, textile dyeing, preserving meats	6
...rine, limestone, ammonia,	Ammonia—soda; evaporating brine	1929 1927 1919	140,234 } ton 121,449 } (ref.) 190,894 tons	3,825 lb. 62,234 17,122	9,474 tons 9,144	$2.15—100 lb., bbl. 2.00 2.29	Free	Cleaning compounds, baking powders, beverages, medicines, fire extinguishers, chemicals	6
...c ore, soda ash, lime stone,	Mixture heated to chromate, treated with H_2SO_4	1929 1927 1919	[14] 37,401 tons 31,462 [14] 24,081		2,926 tons 4,453	7 c. lb. 6½ 11½	1½c. lb.	Leather tanning, textile dyeing and printing, chrome colors and pigments, metal processes	6
... nitrate, H_2SO_4	Byproduct in making nitric acid	1929 1927 1919	91,617 tons 153,615 97,836	91,634 tons		$14.25 ton 5.00 3.50	Free	Pickling metals, textiles, rayon, hydrochloric acid and chemicals	6
... chloride	Electrolysis and evaporation	1929 1927 1919		7,738,862 lb. 1,528,541 39,022		7 c. lb., keg 6½ bag 25	1½c. lb.	Matches, explosives, textiles and dyes, pharmaceuticals, weed killers	6
...l brine; mineral salt	Solar evaporation; mined, crushed	1929 1927 1919	8,543,560 tons 7,568,690 6,882,902	45,837 tons 47,922 62,821	109,222 tons 103,832 121,701	$3.20 ton, tech. 3.28 3.94	7c. 100 lb. in bulk	Alkali and sodium compounds, food, tanning	6
...h, hydrofluoric acid	Neutralization, evaporation	1929 1927 1919	..... 1,534 tons 682	527 tons 496		8¾c. lb. 8½ 14½	25%	Roach and rat poisons, fluxes and enamels, preservative, medicines	6
... chloride, soda ash, lime	Electrolysis of salt; causticising with lime	1929 1927 1919	[7] 758,800 tons 573,417 312,736	172,943 lb. 173,302 42,724	60,534 tons 50,444 82,118	$2.90 } 100 lb. 3.00 } drum, 3.09 } 76%	½c. lb.	Soap, petroleum refining, rayon, chemicals, lye, textiles	6
...altpeter; soda ash and syn- ...nitric acid	Refined saltpeter; nitrogen fixation	1929 1927 1919		930,458 tons 748,782 407,559	9,000 lb.	$2.144—100 lb. 2.464 3.66	Free	Fertilizer, nitric acid, meat preservative, glass, explosives	6
...ia, soda ash; sodium nitrate	Partial oxidation of ammonia, and soda ash; reduction of $NaNO_3$	1929 1927 1919	.... 2,364,000 lb.	312,000 lb. 291,726 2,550,689		7½c. lb., cask 8½ 12½	4½ lb.	Dyes, textiles, meat preservative, pharmaceuticals	7
...oric acid, soda ash and so- ...hydroxide	Controlled reaction of raw materials	1929 1927 1919	146,179 tons 96,481 23,867	8,819 tons 8,385 56 lb.		5½c. } Lb., bbl., 3½ } dibasic 3½ }	1½c. lb. <45% H_2O	Monosodium — baking powder, pharmaceuticals; disodium — textiles, enamels; trisodium — cleaning compounds	7
...oda ash	Fusing raw materials	1929 1927 1919	591,345 } Tons, 504,518 } 40 336,093 } deg.	314,819 lb. 154,059 931,086	79,884 tons 36,954 12,150	70c. } 100 lb., 62.5 } 40 deg. $1.99 }	¾c. lb.	Adhesive, soap, sising, paper and textiles	7
... sulphide, salt cake	Byproduct of barium industry; reducing Na_2SO_4	1929 1927 1919	31,918 tons 38,446 39,735	4,983 tons 5,202 836		3 c. } Lb. drum, 3½ } 60-62% 5 }	¾c. lb. not >35% ¾c. lb. >35%	Sulphur colors and dyes, leather, insecticides	7
									7
...h, SO_2 or sodium bisulphite	Replacement reactions	1929 1927 1919	5,970 tons 5,030 8,666	..... 501 tons 29		2½c. } Lb., bbl., 3½ } crystals 3½ }	¾c. lb.	Textile bleaching, antichlor, photographic developers, antiseptic, preservative	7
...l; coal gas	Mining with hot water	1929 1927 1919	2,362,389 } Long 2,111,618 } tons 1,190,575 } mined	.... 77 long tons, crude	855,183 } Long 789,371 } tons 224,712 } crude	$18.00 } Ton, 18.00 } bulk 27.50 } crude	Free	Sulphuric acid, pulp, rubber, petroleum refining, explosives, fungicide, chemicals	7
...e, sulphur	Chlorine and molten sulphur; byproduct in CCl_4 mfr.	1929 1927 1919	17,827,108 lb. 3,354,965 4,648,066			3¾c. lb. 4	25%	Carbon bisulphide and other chemicals, rubber, sugar, insecticides, pharmaceuticals, textile	7
...one; pyrites; smelter gases	Roasting brimstone or pyrites; from smelter gases	1929 1927 1919	11,958,846 lb. 11,003,719 856,000			9 c. lb. cyl. 9½	25%	Pulp and paper; bleaching straw, silk, oil, sugar juice, flour, foods; preservative	7
...r; iron pyrites; smelter stack	Chamber oxidation process (dilute) contact oxidation (conc.)	1929 1927 1919	8,364,754 } Tons, 7,335,795 } 50 5,552,581 } deg.	8,104 tons 17,435 7,373	3,480 tons 3,766 10,647	$13.20 ton, 66 deg. 12.70 15.84	Free	Fertilizers, petroleum refining, chemicals, coal processing, pickling iron and steel	7
... wine lees; calcium tartrate,	Calcium tartrate, digested with H_2SO_4, evaporated, crystallised	1929 1927 1919	5,906,479 lb. 5,781,166 5,312,965	2,221,503 lb. 2,854,000 654,736		38½c. lb., pwd. 33 2/10 78 5/10	8c. lb.	Baking powders, pharmaceuticals, flavoring, soft drinks	8
... zinc ore, hydrochloric acid	Roasted Zn ores dissolved in HCl; galvanising byproduct	1929 1927 1919	71,938,658 lb. 58,268,485 74,089,063	1,275,053 lb. 939,301 2,016		6½c. lb., gran. 6½ 12	1 1/10c. lb.	Wood preservation, vulcanised fiber, dry batteries, disinfectant, pharmaceuticals	8
...e, coal	American: Air blown through ore and coal; French: Oxidising vapor from boiling spelter bath	1929 1927 1919	158,480 tons 174,105 142,753		17,636 tons 14,494 14,703	6½c. } Lb., lead 10½ } free 9 }	1½c. lb. not > 25% of lead	Rubber, paints, and enamels, oil cloth, printer's ink, medicines	8
...rap and ores, H_2SO_4	Treating zinc dross or scrap with H_2SO_4	1929 1927 1919	..... 20,627,505 lb. 12,941,730	1,818,662 lb. 409,051 231		$3.50—100 lb. 2.90 4.00	¼c. lb.	Zinc pigments, including lithopone, textile, glue, medicines, electrolytic refining of zinc	8

[3] Not incl. products of coke and mfd. gas industry. [4] Incl. ammonia liquor (NH_3 content) (not incl. products of coke ind). [6] Incl. fusel oil. [6] Refined amyl alcohol. [7] Not incl. that made and used in pulp and ...ents Co. only. ...Total for chemical purposes. [11] Not incl. intermediate consumed in fertilizer manufacture. [12] Total crude potash salts. [13] Includes byproduct pyrite and pyrrhotite. [14] Includes neutral chromate.

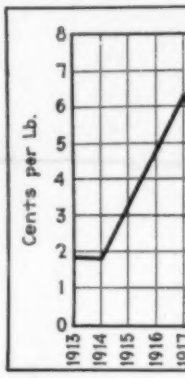


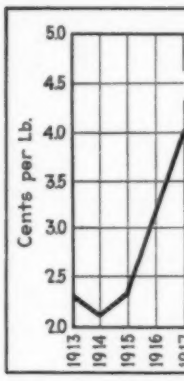


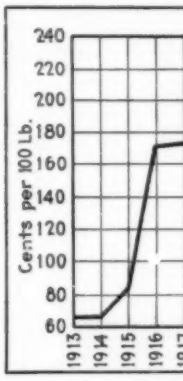
FOR THE

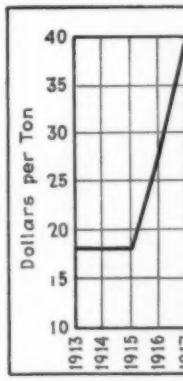
	1927	[illegible]	[illegible]		[illegible]	[illegible]	Soft soap; potassium permanganate; dyes	55
	1927	Not shown	14,759,060		7.2			
	1919	8,358,834	466,620		39.2			
ased ore oxidised with Cl or electrolytically	1929	Not shown	33,709 lb.		16c. lb.	6c. lb.	Lithopone; antiseptics; bleaching; textiles; carbon dioxide	56
	1927		319,332		14.13			
	1919		4,000		59.16			
ide treated with lime and potash alts	1929	Not available	113,480 lb.		19½c. } Lb., casks,	4c. lb.	Prussian blue; textile dyeing; case-hardening iron; cyanides, ferricyanides	57
	1927		159,250		18 } N. Y.			
	1919		515,236		46 }			
	1929	333,465	514,336 } All tons		13c. per unit	Free	Sulphuric acid; sulphur dioxide for paper industry	58
	1927	[12]302,826	250,794 } —		12½			
	1919	420,647	388,973 } 2240 lb.		17			
yproduct in HCl manufacture; vaporating brines	1929	217,626 tons	91,645 tons		$17.74 ton	Free	Kraft paper; glass; sodium sulphide; Glaubers salt	59
	1927	208,565	11,171		20.10			
	1919	179,003	28		17.24			
mmonia-soda; electrolysis; evaporating brines	1929	2,682,216 tons	14,355 tons	77,913,247 lb.	$1.32 —100 lb.	½c. lb.	Glass; soap; chemicals; pulp and paper; water softening; petroleum refining	60
	1927	2,037,808	99,372 lb.	40,802,301	1.325			
	1919	1,390,628	829,266 lb.	100,961,927	1.74			
eutralising acetic acid and recrystallising	1929	592,253 lb.	874,895 lb.		5½c. lb., bbl.	25%	For glacial acetic acid and acetic anhydride; in dyes, textile dyeing, preserving meats	61
	1927	1,854,588	1,113,262		4½			
	1919	2,260,459	.....		8½			
mmonia—soda; evaporating brine	1929	140,234 } ton	3,825 lb.	9,474 tons	$2.15—100 lb., bbl.	Free	Cleaning compounds, baking powders, beverages, medicines, fire extinguishers, chemicals	62
	1927	121,449 } (ref.)	62,234	9,144	2.00			
	1919	190,894 tons	17,122	.....	2.29			
ixture heated to chromate, reated with H_2SO_4	1929	[14] 37,401 tons		2,926 tons	7 c. lb.	1½c. lb.	Leather tanning, textile dyeing and printing, chrome colors and pigments, metal processes	63
	1927	31,462		4,453	6½			
	1919	[14] 24,081		.....	11½			
yproduct in making nitric acid	1929	91,617 tons	91,634 tons		$14.25 ton	Free	Pickling metals, textiles, rayon, hydrochloric acid and chemicals	64
	1927	153,615	.....		5.00			
	1919	97,836	.....		3.50			
lectrolysis and evaporation	1929		7,738,862 lb.		7 c. lb., keg	1½c. lb.	Matches, explosives, textiles and dyes, pharmaceuticals, weed killers	65
	1927		1,528,541		6½ bag			
	1919		39,022		25			
lar evaporation; mined, crushed	1929	8,543,560 tons	45,837 tons	109,222 tons	$3.20 ton, tech.	7c. 100 lb. in bulk	Alkali and sodium compounds, food, tanning	66
	1927	7,568,690	47,922	103,832	3.28			
	1919	6,882,902	62,821	121,701	3.94			
eutralisation, evaporation	1929	.....	527 tons		8½c. lb.	25%	Roach and rat poisons, fluxes and enamels, preservative, medicines	67
	1927	1,534 tons	496		8⅞			
	1919	682	.....		14½			
lectrolysis of salt; causticising with lime	1929	[7] 758,800 tons	172,943 lb.	60,534 tons	$2.90 } 100 lb.	½c. lb.	Soap, petroleum refining, rayon, chemicals, lye, textiles	68
	1927	573,417	173,302	50,444	3.00 } drum,			
	1919	312,736	42,724	82,118	3.09 } 76%			
efined saltpeter; nitrogen fixation	1929		930,458 tons	9,000 lb.	$2.144—100 lb.	Free	Fertilizer, nitric acid, meat preservative, glass, explosives	69
	1927		748,782	.....	2.464			
	1919		407,559	.....	3.66			
artial oxidation of ammonia, and oda ash; reduction of $NaNO_3$	1929	.....	312,000 lb.		7½c. lb., cask	4½ lb.	Dyes, textiles, meat preservative, pharmaceuticals	70
	1927	.....	291,726		8½			
	1919	2,364,000 lb.	2,550,689		12½			
ontrolled reaction of raw materials	1929	146,179 tons	8,819 tons		5½c. } Lb., bbl.,	1½c. lb. <45% H_2O	Monosodium — baking powder, pharmaceuticals; disodium — textiles, enamels; trisodium — cleaning compounds	71
	1927	96,481	8,385		3½ } dibasic			
	1919	23,867	56 lb.		3¼ }			
using raw materials	1929	591,345 } Tons,	314,819 lb.	79,884 tons	7c. } 100 lb.,	½c. lb.	Adhesive, soap, sizing, paper and textiles	72
	1927	504,518 } 40	154,059	36,954	62.5 } 40 deg.			
	1919	336,093 } deg.	931,086	12,150	$1.99 }			
yproduct of barium industry; reducing Na_2SO_4	1929	31,918 tons	4,983 tons		3 c. } Lb. drum,	½c. lb. not >35%	Sulphur colors and dyes, leather, insecticides	73
	1927	38,446	5,202		3½ } 60-62%	½c. lb. >35%		
	1919	39,735	836		5 }	.....		
								74
eplacement reactions	1929	5,970 tons	.....		2c. } Lb., bbl.,	½c. lb.	Textile bleaching, antichlor, photographic developers, antiseptic, preservative	75
	1927	5,030	501 tons		3 } crystals			
	1919	8,666	29		3½ }			
Mining with hot water	1929	2,362,389 } Long	.....	855,183 } Long	$18.01 } Ton,	Free	Sulphuric acid, pulp, rubber, petroleum refining, explosives, fungicide, chemicals	76
	1927	2,111,618 } tons	.....	789,371 } tons	18.01 } bulk			
	1919	1,190,575 } mined	77 long tons, crude	224,712 } crude	27.50 } crude			
Chlorine and molten sulphur; by-product in CCl_4 mfr.	1929	17,827,108 lb.			3½c. lb.	25%	Carbon bisulphide and other chemicals, rubber, sugar, insecticides, pharmaceuticals, textile	77
	1927	3,354,965			4			
	1919	4,648,066			.....			
Roasting brimstone or pyrites; from smelter gases	1929	11,958,846 lb.			9c. lb. cyl.	25%	Pulp and paper; bleaching straw, silk, oil, sugar juice, flour, foods; preservative	78
	1927	11,003,719			9½			
	1919	856,000			.....			
Chamber oxidation process (dilute) contact oxidation (conc.)	1929	8,364,754 } Tons,	8,104 tons	3,480 tons	$13.20 ton, 66 deg.	Free	Fertilizers, petroleum refining, chemicals, coal processing, pickling iron and steel	79
	1927	7,335,795 } 50	17,435	3,766	12.70			
	1919	5,552,581 } deg.	7,373	10,647	15.84			
Calcium tartrate, digested with H_2SO_4, evaporated, crystallised	1929	5,906,479 lb.	2,221,503 lb.		38c. lb., pwd.	8c. lb.	Baking powders, pharmaceuticals, flavoring, soft drinks	80
	1927	5,781,166	2,854,000		33½			
	1919	5,312,965	654,736		78½			
Roasted Zn ores dissolved in HCl; galvanising byproduct	1929	71,938,658 lb.	1,275,053 lb.		6½c. lb., gran.	1 7/16c. lb.	Wood preservation, vulcanised fiber, dry batteries, disinfectant, pharmaceuticals	81
	1927	58,268,485	939,301		6½			
	1919	74,089,063	2,016		12			
American: Air blown through ore and coal; French: Oxidising vapor from boiling spelter bath	1929	158,480 tons		17,636 tons	6½c. } Lb., lead	1½c. lb. not > 25% of lead	Rubber, paints, and enamels, oil cloth, printer's ink, medicines	82
	1927	174,105		14,494	10½ } free			
	1919	142,753		14,703	9 }			
Treating zinc dross or scrap with H_2SO_4	1929	.....	1,818,662 lb.		$3.50—100 lb.	½c. lb.	Zinc pigments, including lithopone, textile, glue, medicines, electrolytic refining of zinc	83
	1927	20,627,505 lb.	409,051		2.90			
	1919	12,941,730	231		4.00			

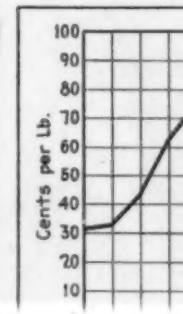
oducts of coke and mfd. gas industry. [6] Incl. ammonia liquor (NH_3 content) (not incl. products of coke ind). [8] Incl. fusel oil. [9] Refined amyl alcohol. [7] Not incl. that made and used in pulp and [11] Not incl. intermediate consumed in fertiliser manufacture. [12] Total crude potash salts. [13] Includes byproduct pyrite and pyrrhotite. [14] Includes neutral chromate.

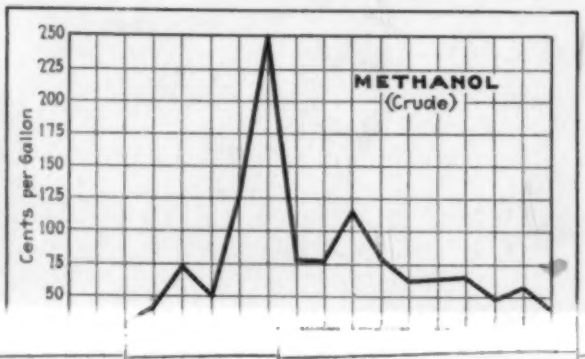




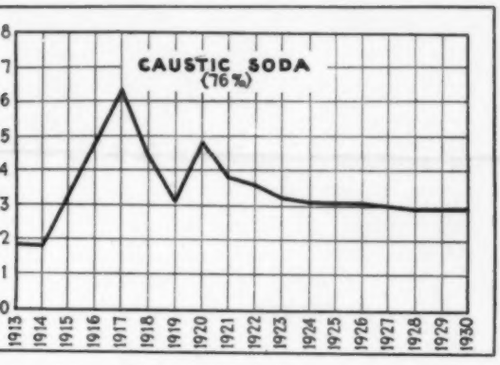


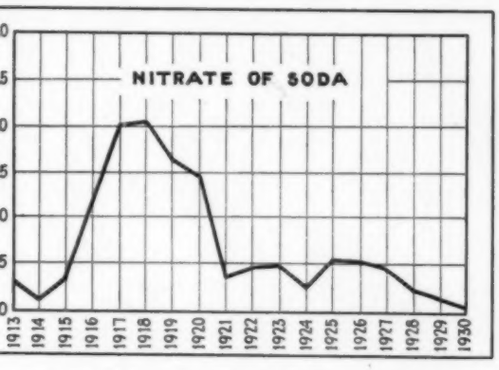


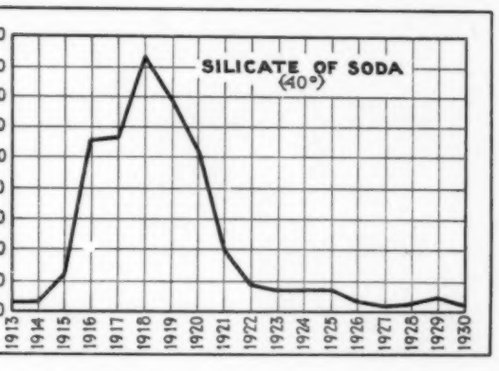


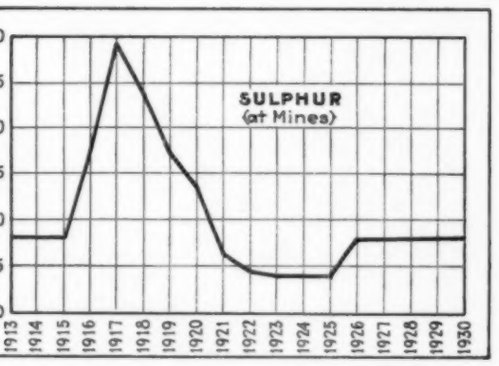


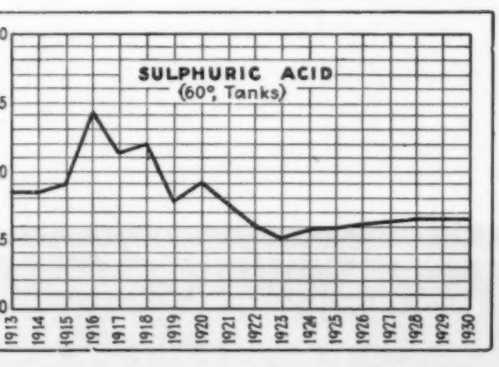
59	Salt Cake	Na_2SO_4	Technical	Salt, H_2SO_4; natural	

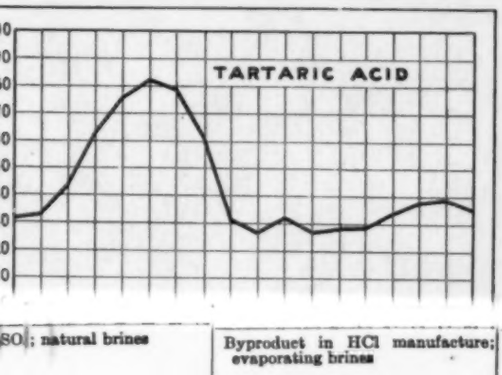




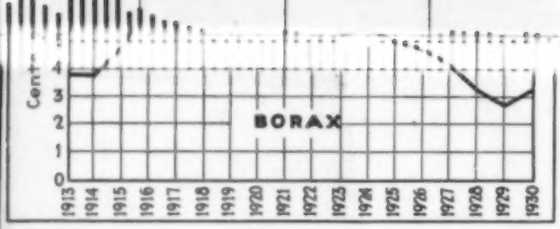


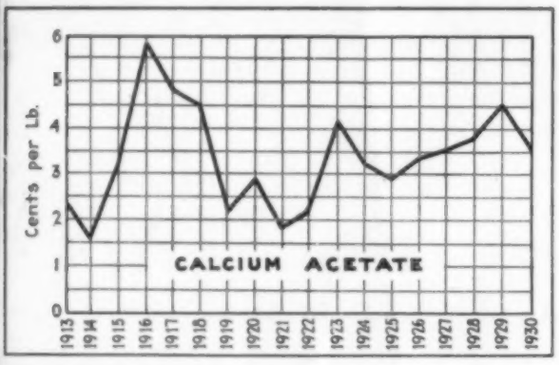


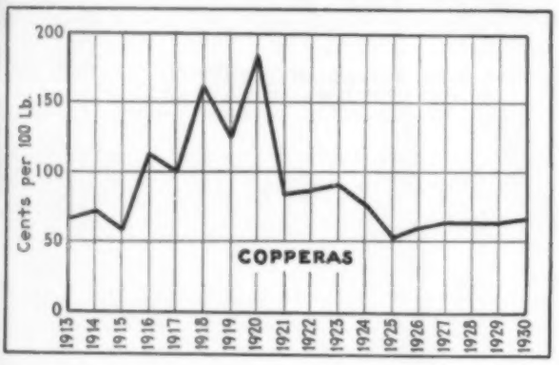


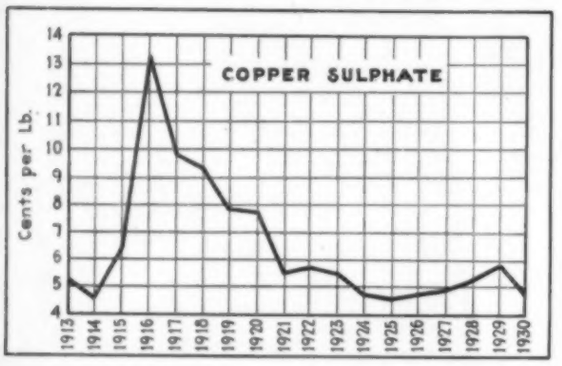


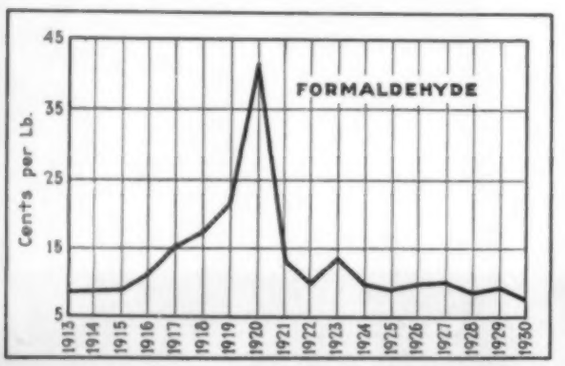
			420,647	388,973] 2240 lb.		V			
SO]; natural brines	Byproduct in HCl manufacture; evaporating brines	1929 1927 1919	217,626 tons 208,565 179,003	91,645 tons 11,171 28		$17.74 ton 20.10 17.24	Free	Kraft paper; phide; Glau

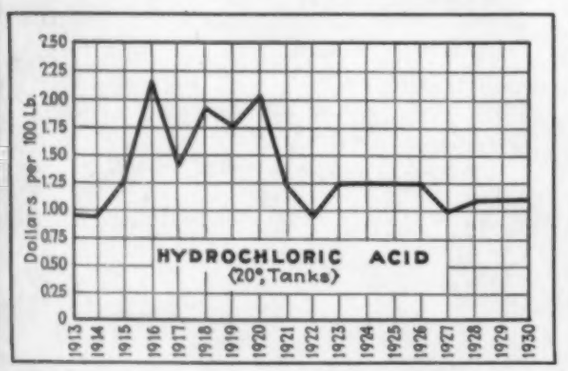






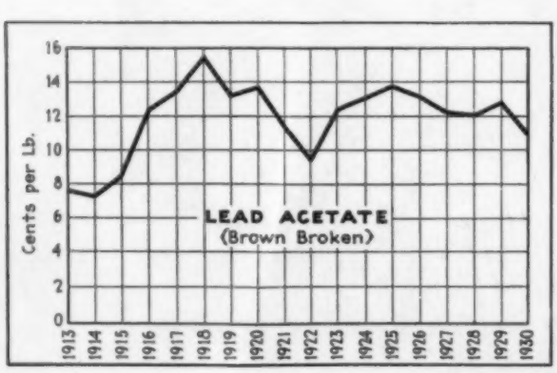


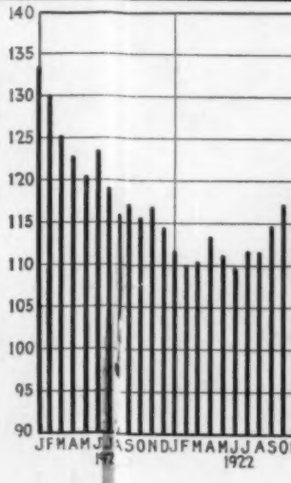




59	**Salt Cake**	Na_2SO_4	Technical	Salt, H_2SO_4; natu
60	**Soda Ash**	Na_2CO_3	Light / Dense } 58% Na_2O	Salt, ammonia, li brine
61	**Sodium Acetate**	$CH_3COONa.3H_2O$	Technical, U. S. P.; fused, recrystallized	Pyroligneous acid, sulphate
62	**Sodium Bicarbonate**	$NaHCO_3.nH_2O$	Technical, refined	Salt brine, lime coal
63	**Sodium Bichromate**	$Na_2Cr_2O_7.2H_2O$	Technical	Chromic ore, soda H_2SO_4
64	**Sodium Bisulphate**	$NaHSO_4$	Technical	Sodium nitrate,
65	**Sodium Chlorate**	$NaClO_3$	Technical; refined, crystals	Sodium chloride
66	**Sodium Chloride**	NaCl	Crude rock; refined table; technical	Natural brine; mi
67	**Sodium Fluoride** (Fluoral)	Na_2F_2	Technical, 96-98%	Soda ash, hydrofl
68	**Sodium Hydroxide** (Caustic Soda)	NaOH	60, 70, 74, 76% Na_2O; solid, fused; 50% sol.	Sodium chloride,
69	**Sodium Nitrate**	$NaNO_3$	Fertiliser: 91-95%; refined: 96-97%	Chile saltpeter; s thetic nitric acid
70	**Sodium Nitrite**	$NaNO_2$	Purity: 96-98%	Ammonia, soda as
71	**Sodium Phosphates**	Na_3PO_4	Mono—NaH_2PO_4 Di—Na_2HPO_4 Tri—Na_3PO_4	Phosphoric acid, dium hydroxide
72	**Sodium Silicate**	$Na_2O.3SiO_2$	30, 40 deg. Bé. sols.; solid, fused	Sand, soda ash
73	**Sodium Sulphide**	Na_2S	Crystal: 30%; fused: 60%	Barium sulphide,
74	**Sodium Sulphate**—See Sodium Bisulphate, Salt Cake, Glaubers Salts			
75	**Sodium Sulphite**	$Na_2SO_3.7H_2O$	Crystals; dry powder	Soda ash, SO_2 or s
76	**Sulphur**	Sn	Crude, refined, flowers; roll, precipitated, pure, U. S. P.	Mineral; coal gas
77	**Sulphur Chlorides**	$S_2Cl_2.SCl_2$	Yellow; red	Chlorine, sulphur
78	**Sulphur Dioxide**	SO_2	Commercial; liquid	Brimstone; pyrites
79	**Sulphuric Acid**	H_2SO_4	50, 60, 66 deg. Bé.; 98-100%, oleum	Sulphur; iron pyrit gases
80	**Tartaric Acid**	$(CHOH)_2.(COOH)_2$	Powder, crystal, granite	Argols, wine lees; H_2SO_4
81	**Zinc Chloride**	$ZnCl_2.nH_2O$	Granular, fused; tablets, solution	Zinc or zinc ore, h
82	**Zinc Oxide**	ZnO	Lead-free: Not < 99% ZnO; leaded: 3-25% lead sulphate; ground, dry and in oil	Zinc ore, coal
83	**Zinc Sulphate**	$ZnSO_4.7H_2O$	Technical; refined: 99.5% crystal salt	Zinc scrap and ore

[1] Total dilute and glacial (except fermentation) incl. acetic anyhdride. [2] Commercial Solvents Co. on textile industry. [8] Total for denatured alcohol by fiscal years. [9] Includes litharge. [10] Total for ch

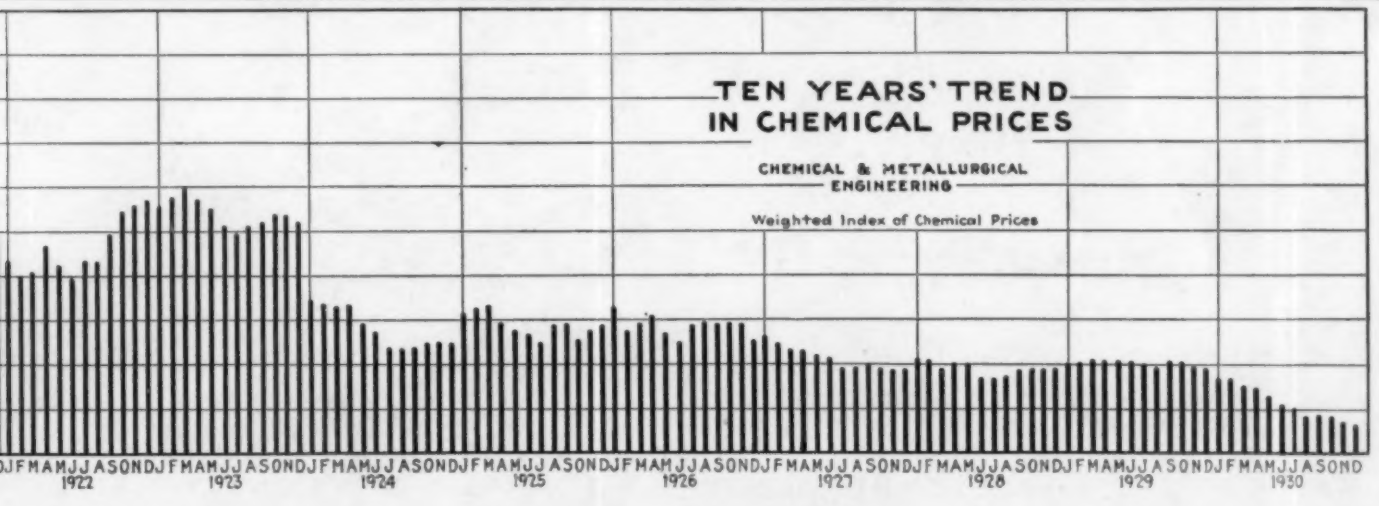




1927	[13]302,826	250,794	—	12½		for paper industry
1919	420,647	388,973	2240 lb.	17		

, H_2SO_4; natural brines	Byproduct in HCl manufacture; evaporating brines	1929 1927 1919	217,626 tons 208,565 179,003	91,645 tons 11,171 28		$17.74 ton 20.10 17.24	Free	Kraft paper; glass; sodium sulphide; Glaubers salt	
, ammonia, lime, coal; natural ne	Ammonia-soda; electrolysis; evaporating brines	1929 1927 1919	2,682,216 tons 2,037,808 1,390,628	14,355 tons 99,372 lb. 829,266 lb.	77,913,247 lb. 40,802,301 100,961,927	$1.32 —100 lb. 1.325 1.74	½c. lb.	Glass; soap; chemicals; pulp and paper; water softening; petroleum refining	
oligneous acid, soda ash, sodium phate	Neutralising acetic acid and recrystallising	1929 1927 1919	592,253 lb. 1,854,588 2,260,459	874,895 lb. 1,113,262		5½c. lb., bbl. 4½ 8½	25%	For glacial acetic acid and acetic anhydride; in dyes, textile dyeing, preserving meats	
brine, limestone, ammonia, al	Ammonia—soda; evaporating brine	1929 1927 1919	140,234 } ton 121,449 } (ref.) 190,894 tons	3,825 lb. 62,234 17,122	9,474 tons 9,144	$2.15—100 lb., bbl. 2.00 2.29	Free	Cleaning compounds, baking powders, beverages, medicines, fire extinguishers, chemicals	
omic ore, soda ash, lime stone, SO_4	Mixture heated to chromate, treated with H_2SO_4	1929 1927 1919	[14] 37,401 tons 31,462 [14] 24,081		2,926 tons 4,453	7 c. lb. 6½ 11½	1½c. lb.	Leather tanning, textile dyeing and printing, chrome colors and pigments, metal processes	
ium nitrate, H_2SO_4	Byproduct in making nitric acid	1929 1927 1919	91,617 tons 153,615 97,836	91,634 tons		$14.25 ton 5.00 3.50	Free	Pickling metals, textiles, rayon, hydrochloric acid and chemicals	
ium chloride	Electrolysis and evaporation	1929 1927 1919		7,738,862 lb. 1,528,541 39,022		7 c. lb., keg 6½ bag 25	1½c. lb.	Matches, explosives, textiles and dyes, pharmaceuticals, weed killers	
ural brine; mineral salt	Solar evaporation; mined, crushed	1929 1927 1919	8,543,560 tons 7,568,690 6,882,902	45,837 tons 47,922 62,821	109,222 tons 103,832 121,701	$3.20 ton, tech. 3.28 3.94	7c. 100 lb. in bulk	Alkali and sodium compounds, food, tanning	
a ash, hydrofluoric acid	Neutralization, evaporation	1929 1927 1919	..... 1,534 tons 682	527 tons 496		8½c. lb. 8 7/10 14½	25%	Roach and rat poisons, fluxes and enamels, preservative, medicines	
ium chloride, soda ash, lime	Electrolysis of salt; causticizing with lime	1929 1927 1919	[7] 758,800 tons 573,417 312,736	172,943 lb. 173,302 42,724	60,534 tons 50,444 82,118	$2.90 } 100 lb. 3.00 } drum, 3.09 } 76%	½c. lb.	Soap, petroleum refining, rayon, chemicals, lye, textiles	
le saltpeter; soda ash and synetic nitric acid	Refined saltpeter; nitrogen fixation	1929 1927 1919		930,458 tons 748,782 407,559	9,000 lb.	$2.144—100 lb. 2.464 3.66	Free	Fertiliser, nitric acid, meat preservative, glass, explosives	
monia, soda ash; sodium nitrate	Partial oxidation of ammonia, and soda ash; reduction of $NaNO_3$	1929 1927 1919	.... 2,364,000 lb.	312,000 lb. 291,726 2,550,689		7½c. lb., cask 8½ 12½	4½ lb.	Dyes, textiles, meat preservative, pharmaceuticals	
sphoric acid, soda ash and so-um hydroxide	Controlled reaction of raw materials	1929 1927 1919	146,179 tons 96,481 23,867	8,819 tons 8,385 56 lb.		5½c. } Lb., bbl., 3½ } dibasic 3½ }	1½c. lb. <45%.H_2O	Monosodium — baking powder, pharmaceuticals; disodium — textiles, enamels; trisodium — cleaning compounds	
d, soda ash	Fusing raw materials	1929 1927 1919	591,345 } Tons, 504,518 } 40 336,093 } deg.	314,819 lb. 154,059 931,086	79,884 tons 36,954 12,150	70c. } 100 lb., 62.5 } 40 deg. $1.99 }	½c. lb.	Adhesive, soap, sising, paper and textiles	
rium sulphide, salt cake	Byproduct of barium industry; reducing Na_2SO_4	1929 1927 1919	31,918 tons 38,446 39,735	4,983 tons 5,202 836		3 c. } Lb. drum, 3½ } 60-62% 5 }	½c. lb. not >35% ½c. lb. >35%	Sulphur colors and dyes, leather, insecticides	
da ash, SO_2 or sodium bisulphite	Replacement reactions	1929 1927 1919	5,970 tons 5,030 8,666	..... 501 tons 29		2½c. } Lb., bbl., 3½ } crystals 3½ }	½c. lb.	Textile bleaching, antichlor, photographic developers, antiseptic, preservative	
neral; coal gas	Mining with hot water	1929 1927 1919	2,362,389 } Long 2,111,618 } tons 1,190,575 } mined	.... 77 long tons, crude	855,183 } Long 789,371 } tons 224,712 } crude	$18.00 } Ton, 18.00 } bulk 27.50 } crude	Free	Sulphuric acid, pulp, rubber, petroleum refining, explosives, fungicide, chemicals	
lorine, sulphur	Chlorine and molten sulphur; byproduct in CCl_4 mfr.	1929 1927 1919	17,827,108 lb. 3,354,965 4,648,066			3½c. lb. 4	25%	Carbon bisulphide and other chemicals, rubber, sugar, insecticides, pharmaceuticals, textile	
mstone; pyrites; smelter gases	Roasting brimstone or pyrites; from smelter gases	1929 1927 1919	11,958,846 lb. 11,003,719 856,000			9 c. lb. cyl. 9½	25%	Pulp and paper; bleaching straw, silk, oil, sugar juice, flour foods; preservative	
phur; iron pyrites; smelter stack ses	Chamber oxidation process (dilute) contact oxidation (conc.)	1929 1927 1919	8,364,754 } Tons, 7,335,795 } 50 5,552,581 } deg.	8,104 tons 17,435 7,373	3,480 tons 3,766 10,647	$13.20 ton, 66 deg. 12.70 15.84	Free	Fertilisers, petroleum refining, chemicals, coal processing, pickling iron and steel	
gols, wine lees; calcium tartrate, $_2SO_4$	Calcium tartrate, digested with H_2SO_4, evaporated, crystallized	1929 1927 1919	5,906,479 lb. 5,781,166 3,312,965	2,221,503 lb. 2,854,000 654,736		38½c. lb., pwd. 33 3/10 78 7/10	8c. lb.	Baking powders, pharmaceuticals, flavoring, soft drinks	
c or zinc ore, hydrochloric acid	Roasted Zn ores dissolved in HCl; galvanising byproduct	1929 1927 1919	71,938,658 lb. 58,268,485 74,089,063	1,275,053 lb. 939,301 2,016		6½c. lb., gran. 6½ 12	1 7/10c. lb.	Wood preservation, vulcanized fiber, dry batteries, disinfectant, pharmaceuticals	
c ore, coal	American: Air blown through ore and coal; French: Oxidising vapor from boiling spelter bath	1929 1927 1919	158,480 tons 174,105 142,753		17,636 tons 14,494 14,703	6½c. } Lb., lead 10½ } free 9 }	1½c. lb. not > 25% of lead	Rubber, paints, and enamels, cloth, printer's ink, medicine	
c scrap and ores, H_2SO_4	Treating zinc dross or scrap with H_2SO_4	1929 1927 1919	..... 20,627,505 lb. 12,941,730	1,818,662 lb. 409,051 231		$3.50—100 lb. 2.90 4.00	½c. lb.	Zinc pigments, including lithopone, textile, glue, medicine; electrolytic refining of zinc	

Solvents Co. only. [5] Not incl. products of coke and mfd. gas industry. [6] Incl. ammonia liquor (NH_3 content) (not incl. products of coke ind). [8] Incl. fusel oil. [9] Refined amyl alcohol. [7] Not incl. that made and used in pulp. [10] Total for chemical purposes. [11] Not incl. intermediate consumed in fertilizer manufacture. [12] Total crude potash salts. [13] Includes byproduct pyrite and pyrrhotite. [14] Includes neutral chromate.


TEN YEARS' TREND
IN CHEMICAL PRICES
CHEMICAL & METALLURGICAL ENGINEERING
Weighted Index of Chemical Prices
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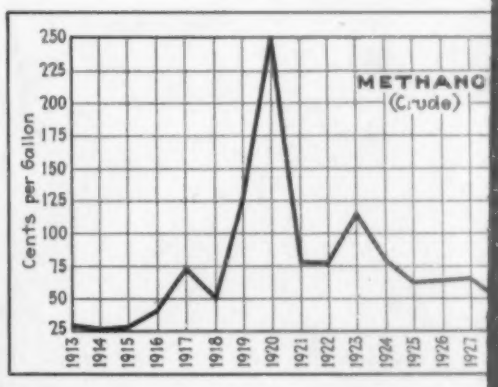
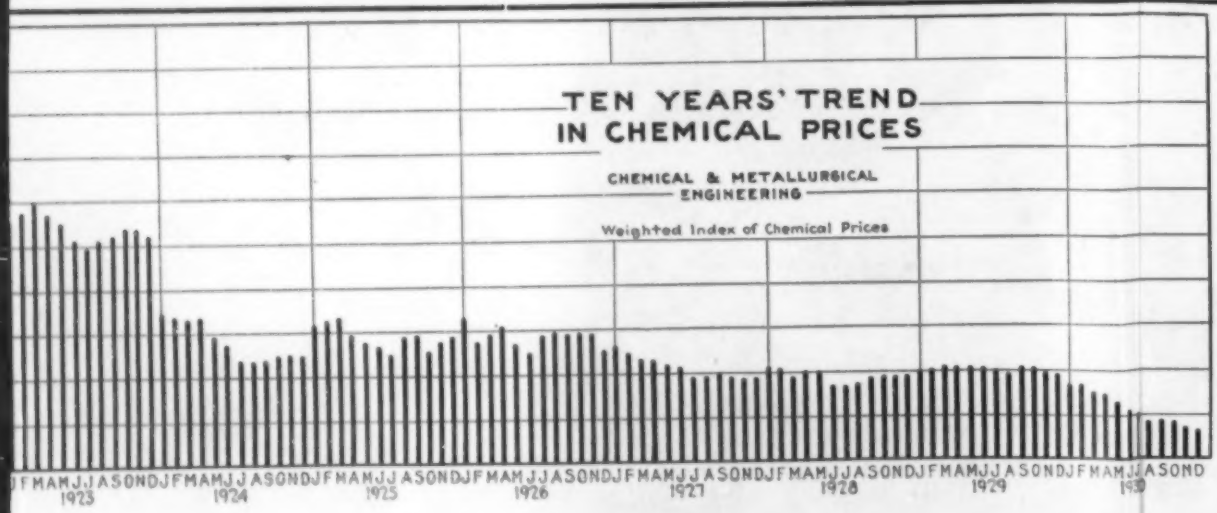
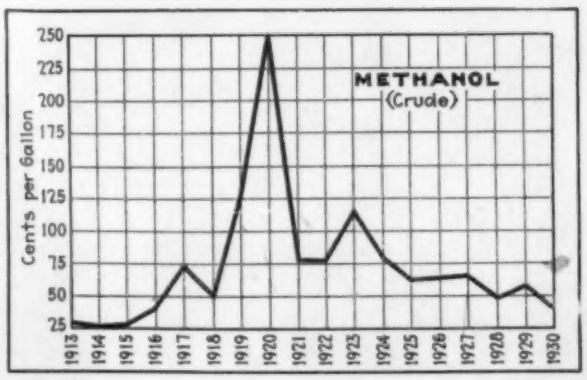


		1927 1919	[13]302,826 420,647	250,794 } = 388,973 } 2240 lb.		12½ 17		for paper industry	
...e	Byproduct in HCl manufacture; evaporating brines	1929 1927 1919	217,626 tons 208,565 179,003	91,645 tons 11,171 28		$17.74 ton 20.10 17.24	Free	Kraft paper; glass; sodium sulphide; Glaubers salt	59
...l; natural	Ammonia-soda; electrolysis; evaporating brines	1929 1927 1919	2,682,216 tons 2,037,808 1,390,628	14,355 tons 99,372 lb. 829,266 lb.	77,913,247 lb. 40,802,301 100,961,927	$1.32 —100 lb. 1.325 1.74	¼c. lb.	Glass; soap; chemicals; pulp and paper; water softening; petroleum refining	60
...h, sodium	Neutralising acetic acid and recrystallising	1929 1927 1919	592,253 lb. 1,854,588 2,260,459	874,895 lb. 1,113,262		5½c. lb., bbl. 4½ 8½	25%	For glacial acetic acid and acetic anhydride; in dyes, textile dyeing, preserving meats	61
...ammonia,	Ammonia—soda; evaporating brine	1929 1927 1919	140,234 } ton 121,449 } (ref.) 190,894 tons	3,825 lb. 62,234 17,122	9,474 tons 9,144	$2.15—100 lb., bbl. 2.00 2.29	Free	Cleaning compounds, baking powders, beverages, medicines, fire extinguishers, chemicals	62
...ime stone,	Mixture heated to chromate, treated with H_2SO_4	1929 1927 1919	[14] 37,401 tons 31,462 [14] 24,081		2,926 tons 4,453	7 c. lb. 6½ 11½	1¼c. lb.	Leather tanning, textile dyeing and printing, chrome colors and pigments, metal processes	63
	Byproduct in making nitric acid	1929 1927 1919	91,617 tons 153,615 97,836	91,634 tons		$14.25 ton 5.00 3.50	Free	Pickling metals, textiles, rayon, hydrochloric acid and chemicals	64
	Electrolysis and evaporation	1929 1927 1919		7,738,862 lb. 1,528,541 39,022		7 c. lb., keg 6½ bag 25	1¼c. lb.	Matches, explosives, textiles and dyes, pharmaceuticals, weed killers	65
...alt	Solar evaporation; mined, crushed	1929 1927 1919	8,543,560 tons 7,568,690 6,882,902	45,837 tons 47,922 62,821	109,222 tons 103,832 121,701	$3.20 ton, tech. 3.28 3.94	7c. 100 lb. in bulk	Alkali and sodium compounds, food, tanning	66
...id	Neutralization, evaporation	1929 1927 1919	..... 1,534 tons 682	527 tons 496		8½c. lb. 8 7/10 14½	25%	Roach and rat poisons, fluxes and enamels, preservative, medicines	67
...h, lime	Electrolysis of salt; causticizing with lime	1929 1927 1919	[7] 758,800 tons 573,417 312,736	172,943 lb. 173,302 42,724	60,534 tons 50,444 82,118	$2.90 } 100 lb. 3.00 } drum, 3.09 } 76%	¼c. lb.	Soap, petroleum refining, rayon, chemicals, lye, textiles	68
...n and syn-	Refined saltpeter; nitrogen fixation	1929 1927 1919		930,458 tons 748,782 407,559	9,000 lb.	$2.144—100 lb. 2.464 3.66	Free	Fertilizer, nitric acid, meat preservative, glass, explosives	69
...um nitrate	Partial oxidation of ammonia, and soda ash; reduction of $NaNO_3$	1929 1927 1919	.... 2,364,000 lb.	312,000 lb. 291,726 2,550,689		7½c. lb., cask 8½ 12½	4½ lb.	Dyes, textiles, meat preservative, pharmaceuticals	70
...sh and so-	Controlled reaction of raw materials	1929 1927 1919	146,179 tons 96,481 23,867	8,819 tons 8,385 56 lb.		5½c. } Lb., bbl., dibasic 3½ 3½	1½c. lb. <45% H_2O	Monosodium — baking powder, pharmaceuticals; disodium — textiles, enamels; trisodium — cleaning compounds	71
	Fusing raw materials	1929 1927 1919	591,345 } Tons, 40 deg. 504,518 } 336,093 }	314,819 lb. 154,059 931,086	79,884 tons 36,954 12,150	70c. } 100 lb., 40 deg. 62.5 $1.99 }	¼c. lb.	Adhesive, soap, sizing, paper and textiles	72
...ake	Byproduct of barium industry; reducing Na_2SO_4	1929 1927 1919	31,918 tons 38,446 39,735	4,983 tons 5,202 836		3 c. } Lb. drum, 60-62% 3½ 5	¼c. lb. not >35% ¼c. lb. >35%	Sulphur colors and dyes, leather, insecticides	73
									74
...bisulphite	Replacement reactions	1929 1927 1919	5,970 tons 5,030 8,666	..... 501 tons 29		2½c. } Lb., bbl., crystals 3½ 3½	¼c. lb.	Textile bleaching, antichlor, photographic developers, antiseptic, preservative	75
	Mining with hot water	1929 1927 1919	2,362,389 } Long tons mined 2,111,618 } 1,190,575 }	.... 77 long tons, crude	855,183 } Long tons crude 789,371 } 224,712 }	$18.00 } Ton, bulk crude 18.00 } 27.50 }	Free	Sulphuric acid, pulp, rubber, petroleum refining, explosives, fungicide, chemicals	76
	Chlorine and molten sulphur; byproduct in CCl_4 mfr.	1929 1927 1919	17,827,108 lb. 3,354,965 4,648,066			3½c. lb. 4	25%	Carbon bisulphide and other chemicals, rubber, sugar, insecticides, pharmaceuticals, textile	77
...elter gases	Roasting brimstone or pyrites; from smelter gases	1929 1927 1919	11,958,846 lb. 11,003,719 856,000			9 c. lb. cyl. 9½	25%	Pulp and paper; bleaching straw, silk, oil, sugar juice, flour, foods; preservative	78
...melter stack	Chamber oxidation process (dilute) contact oxidation (conc.)	1929 1927 1919	8,364,754 } Tons, 50 deg. 7,335,795 } 5,552,581 }	8,104 tons 17,435 7,373	3,480 tons 3,766 10,647	$13.20 ton, 66 deg. 12.70 15.84	Free	Fertilizers, petroleum refining, chemicals, coal processing, pickling iron and steel	79
...m tartrate,	Calcium tartrate, digested with H_2SO_4, evaporated, crystallised	1929 1927 1919	5,906,479 lb. 5,781,166 5,312,965	2,221,503 lb. 2,854,000 654,736		38½c. lb., pwd. 33½ 78½	8c. lb.	Baking powders, pharmaceuticals, flavoring, soft drinks	80
...hloric acid	Roasted Zn ores dissolved in HCl; galvanising byproduct	1929 1927 1919	71,938,658 lb. 58,268,485 74,089,063	1,275,053 lb. 939,301 2,016		6½c. lb., gran. 6½ 12	1 7/10c. lb.	Wood preservation, vulcanised fiber, dry batteries, disinfectant, pharmaceuticals	81
	American: Air blown through ore and coal; French: Oxidising vapor from boiling spelter bath	1929 1927 1919	158,480 tons 174,105 142,753		17,636 tons 14,494 14,703	6½c. } Lb., lead free 10½ 9 }	1¼c. lb. not > 25% of lead	Rubber, paints, and enamels, oil cloth, printer's ink, medicines	82
...SO_4	Treating zinc dross or scrap with H_2SO_4	1929 1927 1919	..... 20,627,505 lb. 12,941,730	1,818,662 lb. 409,051 231		$3.50—100 lb. 2.90 4.00	¼c. lb.	Zinc pigments, including lithopone, textile, glue, medicines, electrolytic refining of zinc	83

[2] Not incl. products of coke and mfd. gas industry. [4] Incl. ammonia liquor (NH_3 content) (not incl. products of coke ind). [5] Incl. fusel oil. [6] Refined amyl alcohol. [7] Not incl. that made and used in pulp and ...al purposes. [11] Not incl. intermediate consumed in fertilizer manufacture. [13] Total crude potash salts. [13] Includes byproduct pyrite and pyrrhotite. [14] Includes neutral chromate.





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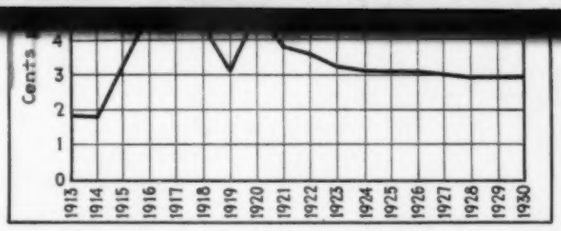
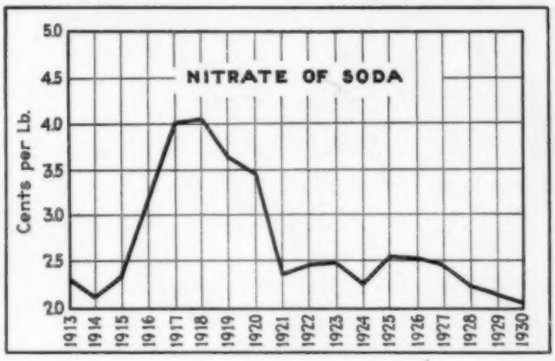
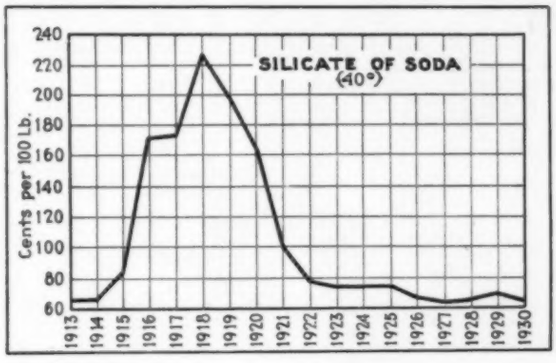
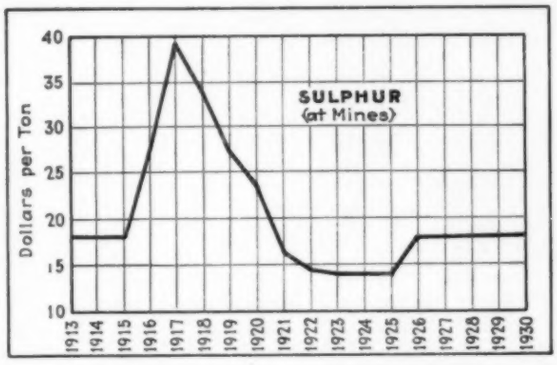
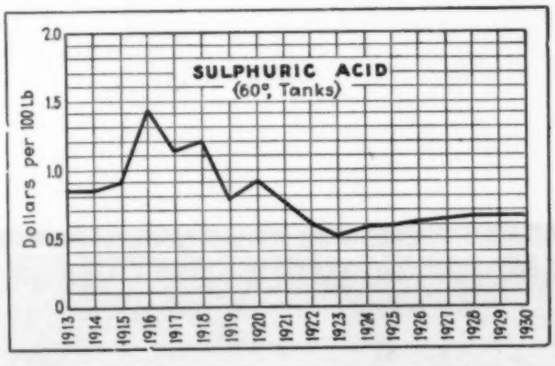
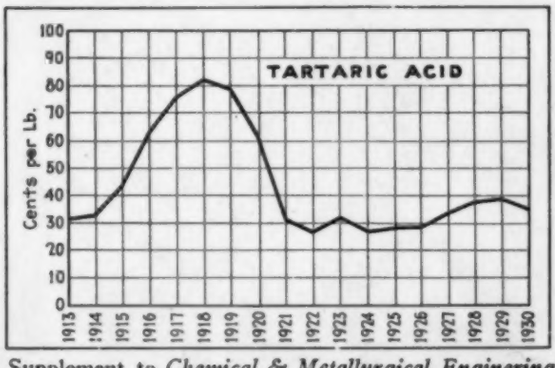

Cents
4
3
2
1
0
1913 1914 1915 1916 1917 1918 1919 1920 1921 1922 1923 1924 1925 1926 1927 1928 1929 1930


NITRATE OF SODA
Cents per Lb.
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1913 1914 1915 1916 1917 1918 1919 1920 1921 1922 1923 1924 1925 1926 1927 1928 1929 1930


SILICATE OF SODA
(40°)
Cents per 100 Lb.
240
220
200
180
160
140
120
100
80
60
1913 1914 1915 1916 1917 1918 1919 1920 1921 1922 1923 1924 1925 1926 1927 1928 1929 1930


SULPHUR
(at Mines)
Dollars per Ton
40
35
30
25
20
15
10
1913 1914 1915 1916 1917 1918 1919 1920 1921 1922 1923 1924 1925 1926 1927 1928 1929 1930


SULPHURIC ACID
(60°, Tanks)
Dollars per 100 Lb
2.0
1.5
1.0
0.5
0
1913 1914 1915 1916 1917 1918 1919 1920 1921 1922 1923 1924 1925 1926 1927 1928 1929 1930


TARTARIC ACID
Cents per Lb.
100
90
80
70
60
50
40
30
20
10
0
1913 1914 1915 1916 1917 1918 1919 1920 1921 1922 1923 1924 1925 1926 1927 1928 1929 1930